3. Analysis of Strategies with Policies from *Scenarios for a Clean Energy Future*

In addition to the reference case and advanced technology case, which were analyzed in Chapter 2, the letter of request from Senators Jeffords and Lieberman asked the Energy Information Administration (EIA) to analyze the impacts of emissions limits on electricity generators in two cases incorporating the policies from the interlaboratory study *Scenarios for a Clean Energy Future* (*CEF*).[30] As discussed in Chapter 1, *CEF* proposed two sets of policies in moderate and advanced cases to reduce energy consumption and carbon dioxide (CO_2) emissions. The *CEF* analysis was conducted using a revised version of EIA's National Energy Modeling System (NEMS) used for the *Annual Energy Outlook 1999* (*AEO99*), referred to as *CEF*-NEMS.

For this analysis, the *CEF* assumptions were implemented as described in this chapter in the version of NEMS used for the *Annual Energy Outlook 2001* (*AEO2001*), published in December 2000.[31] The cases that implement the *CEF* policies are denoted as the *CEF-JL* (*Clean Energy Futures* – Jeffords / Lieberman) moderate and advanced cases. Chapter 1 describes the most significant changes in the model methodologies and assumptions between the *AEO99* and *AEO2001* versions of NEMS, the revisions to the *AEO99* version of NEMS in *CEF*, and the revisions included in the reference case of this analysis from the *AEO2001* version of NEMS.

This chapter describes the various *CEF* policies in the moderate and advanced cases and their implementation in both the *CEF* analysis and this analysis on a sector-by-sector basis and discusses the feasibility of the impacts of the policies in *CEF*. The impact of the *CEF* policies in the *CEF-JL* cases, which incorporate the *CEF* policies in the current version of NEMS, compared to the reference case is then discussed, followed by the impact of the emissions limits on the *CEF-JL* cases. The same emissions limits on electricity generators (excluding cogenerators) are applied to the *CEF-JL* cases as to the reference and advanced technology cases in Chapter 2.[32] The start date for emissions reductions is 2002. By 2007, nitrogen oxides (NO_x) emissions are reduced to 75 percent below 1997 levels, sulfur dioxide (SO_2) emissions to 75 percent below the full implementation of the Phase II requirements under Title IV of the Clean Air Act Amendments of 1990 (CAAA90), mercury (Hg) emissions to 90 percent below 1999 levels, and CO_2 emissions to 1990 levels.

The authors of the *CEF* report proposed a number of policies for the end-use demand and electricity generation sectors, including increased research and development funding, equipment standards, financial incentives, voluntary programs, and other regulatory initiatives. The purpose of these policies was to promote the development and adoption of more efficient technologies, reduce energy service demand, and encourage the use of cleaner, less carbon-intensive fuels. One system-wide policy is the imposition of a domestic CO_2 trading system with an assumed permit price of $50 per metric ton carbon equivalent, which would be announced in 2002, implemented in 2005, and applied to all energy sectors and all fuels. This policy is assumed in the *CEF-JL* advanced cases only, both with and without the emissions limits on electricity generators. In the moderate *CEF-JL* case with emissions limits, the only emissions costs are those imposed on electricity generators as a result of the emissions limits.

In the request for this analysis, EIA was asked to assume the *CEF* scenarios in order to analyze the impacts of the emissions limits on projections with lower energy demand. In accordance with this request, the impacts of the policies from *CEF* are implemented for this analysis. These impacts are due to assumed changes in consumer behavior that are not consistent with historical behavior patterns, result from research and development funding increases that have not occurred and for which there is no analytical basis for the impacts of the funding on technological improvements, and voluntary or information programs for which there is also no analytical basis for the impacts.

The results of the *CEF-JL* cases should not be interpreted as an EIA analysis of the *CEF* policies, because, as noted

[30] Interlaboratory Working Group, *Scenarios for a Clean Energy Future*, ORNL / CON-476 and LBNL-44029 (Oak Ridge National Laboratory, Oak Ridge, TN, and Lawrence Berkeley National Laboratory, Berkeley, CA, November 2000), web site www.ornl.gov / ORNL / Energy_Eff / CEFOnep.pdf.

[31] Energy Information Administration, *Annual Energy Outlook 2001*, DOE / EIA-0383(2001)(Washington, DC, December 2000), web site www.eia.doe.gov / oiaf / aeo / index.html.

[32] At this time, emissions limits on cogenerators are not represented.

later in this chapter, EIA does not necessarily agree with the assumptions and projected levels of impacts in the *CEF* analysis. In addition, many of the *CEF* policies are dependent on increases in research and development funding or require investments in more efficient or less carbon-intensive equipment by the public and private sectors. The total cost of achieving these policies is not quantified in this analysis but is likely to be significant, and although the environmental benefits of the advanced case would be higher than those of the moderate case, the associated costs would be higher as well.

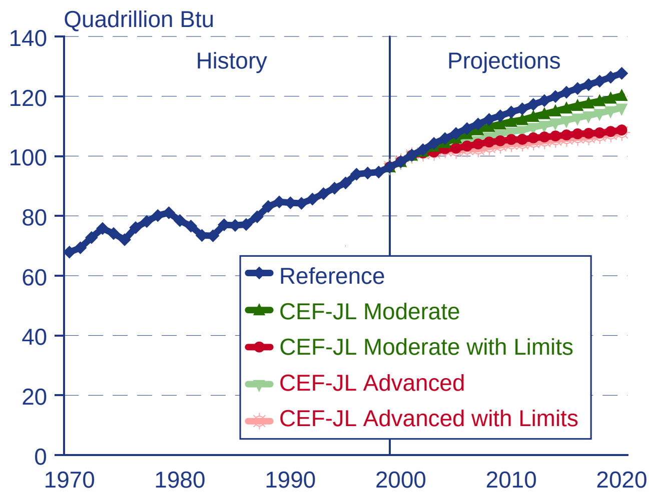
Summary of Impacts of *CEF* Policies and Emissions Limits in the *CEF-JL* Cases

Overall, primary energy consumption in 2020 is projected to be reduced from 128 quadrillion British thermal units (Btu) in the reference case without emissions limits to 120 quadrillion Btu and 109 quadrillion Btu in the *CEF-JL* moderate and advanced cases without emissions limits, reducing consumption by 6 and 15 percent, respectively (Figure 21 and Table 14). The projected annual average decline in primary energy intensity—defined as total energy consumption per dollar of gross domestic product (GDP)—between 1999 and 2020 is 1.9 and 2.4 percent in the *CEF-JL* moderate and advanced cases, respectively, compared to 1.6 percent in the reference case (Figure 22). In the residential and commercial sectors, a number of *CEF* policies were aimed at reducing the demand for electricity, which has the largest projected demand reduction in both sectors. In addition, in the advanced case, projected average delivered electricity prices in 2020 are higher than in the reference case, 6.6 cents per kilowatthour compared with 6.1 cents per kilowatthour hour, due to the $50 carbon fee. Purchased electricity demand is also projected to be lower in the industrial sector in both cases, relative to the reference case, particularly in the *CEF-JL* advanced case which assumes more available renewables and the $50 carbon fee. Total projected electricity consumption in 2020 is reduced by 12 percent and 19 percent in the *CEF-JL* moderate and advanced cases, respectively, relative to the reference case.

In the electricity generation sector, coal-fired generation in 2020 is projected to be very similar in the *CEF-JL* moderate case to the reference case. Projected natural-gas-fired generation is reduced by 39 percent in the *CEF-JL* moderate case compared to the reference case because the reduced projected demand for electricity reduces the requirements for new generation capacity which is largely natural-gas-fired. In 2020, renewable generation is projected to be higher by 4 percent in the *CEF-JL* moderate case, relative to the reference case. Although natural-gas-fired capacity additions and generation are lower in the *CEF-JL* moderate case than in the reference case, cumulative capacity additions of natural-gas-fired turbines and combined-cycle plants are projected to total 160 gigawatts by 2020, compared to 13 gigawatts of new renewable capacity, because natural-gas-fired plants remain more economical than renewable sources.

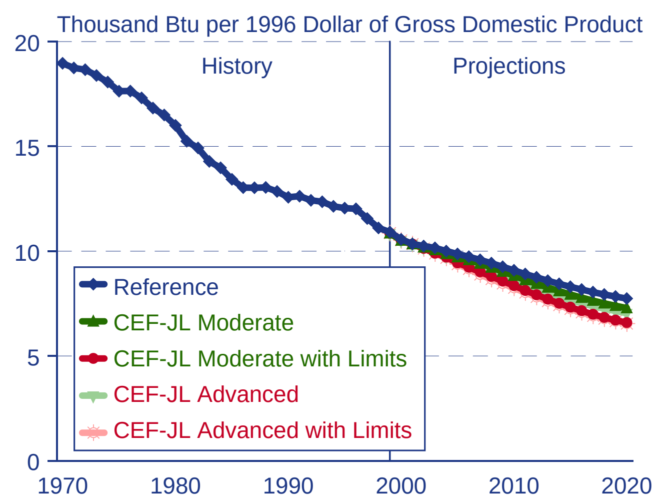
In the *CEF-JL* advanced case, projected coal-fired generation is reduced by 32 percent in 2020 relative to the reference case due to policies that encourage the use of natural gas and renewable generation, including the $50 carbon fee and a *CEF* policy to reduce particulate matter emissions by lowering the SO_2 emissions level mandated in CAAA90. In the advanced case, projected natural gas generation is lower than in the reference case but

Figure 21. Energy Consumption in Five Cases, 1970-2020



Source: National Energy Modeling System, runs SCENABS.D080301A, SCENCBS.D080301A, SCENCEM.D081601A, SCENDBS.D092601B, and SCENDEMR.D092701A.

Figure 22. Primary Energy Intensity in Five Cases, 1970-2020



Source: National Energy Modeling System, runs SCENABS.D080301A, SCENCBS.D080301A, SCENCEM.D081601A, SCENDBS.D092601B, and SCENDEMR.D092701A.

Table 14. Energy Market Projections in the *CEF-JL* Moderate and Advanced Cases, 2020

Projections	1999	2020				
			CEF-JL Moderate		*CEF-JL* Advanced	
		Reference	Without Emissions Limits	With Emissions Limits	Without Emissions Limits	With Emissions Limits
Production (Quadrillion Btu)	**73.3**	**87.6**	**82.8**	**79.0**	**76.9**	**75.9**
Petroleum	15.1	15.2	14.3	14.8	14.2	14.5
Natural Gas	19.2	30.1	26.1	28.1	25.5	26.6
Coal	23.1	27.1	26.5	16.8	19.3	16.4
Nuclear Power	7.8	6.5	6.4	6.9	6.1	6.6
Renewable Energy	6.5	8.4	8.6	11.5	10.8	11.1
Primary Energy Consumption (Quadrillion Btu)	**96.3**	**127.7**	**120.2**	**116.2**	**108.7**	**107.9**
Petroleum	37.9	50.4	47.9	47.9	42.4	42.5
Natural Gas	22.3	35.9	31.3	33.8	30.7	32.0
Coal	21.4	26.3	25.8	15.7	18.3	15.5
Nuclear Power	7.8	6.5	6.4	6.9	6.1	6.6
Renewable Energy	6.5	8.4	8.6	11.5	10.8	11.1
Change in Primary Energy Intensity (Annual Percent Change, 1999-2020)	**—**	**-1.6**	**-1.9**	**-2.0**	**-2.4**	**-2.4**
Delivered Energy Consumption (Quadrillion Btu)	**72.1**	**97.3**	**92.1**	**91.6**	**84.7**	**84.6**
Residential	10.7	13.5	12.6	12.2	11.6	11.5
Commercial	7.6	10.9	10.0	9.8	9.7	9.6
Industrial	27.6	34.7	33.2	33.2	32.0	32.0
Transportation	26.3	38.2	36.3	36.3	31.5	31.5
Electricity Sales (Billion Kilowatthours)	**3,294**	**4,763**	**4,197**	**3,910**	**3,862**	**3,855**
Electricity Generation, Excluding Cogenerators (Billion Kilowatthours)	3,369	4,821	4,231	3,893	3,883	3,878
Coal	1,830	2,302	2,296	1,284	1,567	1,276
Petroleum	85	23	21	11	10	9
Natural Gas	370	1,488	908	1,330	1,181	1,416
Nuclear Power	730	610	595	646	575	617
Renewables	355	399	413	624	551	561
Electricity Generation by Cogenerators (Billion Kilowatthours)	303	440	443	607	470	463
Prices						
World Oil Price (1999 Dollars per Barrel)	17.22	22.41	22.41	22.41	22.41	22.41
Natural Gas Wellhead Price (1999 Dollars per Thousand Cubic Feet)	2.08	3.10	2.48	2.82	2.36	2.61
Coal Minemouth Price (1999 Dollars per Short Ton)	17.13	12.93	12.78	13.47	11.51	13.45
Average Delivered Electricity Price (1999 Cents per Kilowatthour)	6.7	6.1	6.0	7.2	6.6	6.6
Cumulative Resource Cost for Electricity Generation, 2001-2020 (Billion 1999 Dollars)	**—**	**2,031**	**1,751**	**1,913**	**1,682**	**1,811**
Emissions[a]						
CO_2 (Million Metric Tons Carbon Equivalent)[b]	1,511	2,044	1,914	1,690	1,615	1,558
SO_2 (Million Tons)	13.5	9.0	9.0	2.2	4.5	2.2
NO_x (Million Tons)	5.4	4.5	4.3	1.7	3.2	1.6
Hg (Tons)	43.4	45.2	46.2	4.3	29.4	4.3
Allowance Prices						
CO_2 (1999 Dollars per Metric Ton Carbon Equivalent)	0	0	0	68	50	50
SO_2 (1999 Dollars per Ton)	0	200	184	905	707	670
NO_x (1999 Dollars per Ton)[c]	0	0	0	81	0	0
Hg (Million 1999 Dollars per Ton)	0	0	0	468	0	391

[a] CO_2 emissions are from all energy sectors. Other emissions are from electricity generators, excluding cogenerators.
[b] CO_2 emissions are from energy combustion only and do not include emissions from energy production or industrial processes.
[c] Regional NO_x limits are included in the reference case, but the corresponding allowance costs are not included in the table because they are not comparable to a national NO_x limit.
Source: National Energy Modeling System, runs SCENABS.D080301A, SCENCBS.D080301A, SCENCEM.D081601A, SCENDBS.D092601B, and SCENDEMR.D092701A.

has a similar market share in 2020. In 2020, renewable generation is projected to be higher by 38 percent in the *CEF-JL* advanced case, relative to the reference case, because the renewable portfolio standard (which requires a specified percentage of electricity sales to be generated from renewable sources other than hydropower), the extension of production tax credits for renewables, and the $50 carbon fee encourage the additional renewable generation. By 2020, cumulative capacity additions of renewable sources are projected to be 29 gigawatts higher than in the reference case.

In 2020, nuclear generation is projected to raise its share of the generation market, excluding cogeneration, from 13 percent in the reference case to 14 and 15 percent in the *CEF-JL* moderate and advanced cases, respectively, but nuclear generation is projected to be slightly lower across the cases due to the lower electricity demand. No new nuclear plants are constructed by 2020, and nuclear plant retirements are projected to be higher in the *CEF-JL* cases than in the reference case because lower projected natural gas prices in the *CEF-JL* cases improve the economics of new plant construction relative to the costs of continuing to operate existing nuclear plants.

Projected petroleum consumption in 2020 is lower by 5 and 16 percent in the moderate and advanced cases, respectively. Petroleum consumption is reduced largely due to *CEF* policies to reduce light-duty vehicle travel and improve the efficiency of all vehicles in the transportation sector, which is almost entirely dependent on petroleum. However, some reductions in petroleum demand are also projected to occur in the industrial sector due to boiler and process efficiency improvements and more rapid equipment retirement rates.

In 2020, total natural gas consumption is projected to be lower by 13 and 15 percent in the *CEF-JL* moderate and advanced cases, relative to the reference case, due to efficiency improvements in the end-use sectors that reduce the demand for natural gas and electricity, leading to further reductions in natural gas generation. Total projected coal consumption is also lower by 2 and 30 percent in the moderate and advanced cases due to reduced coal-fired generation. Renewable sources are the only energy sources for which projected consumption is higher in the *CEF-JL* cases than in the reference case, by 3 percent and 29 percent in the moderate and advanced cases, respectively, mainly due to more renewable generation but also due to higher use of renewables in the industrial sector in the advanced case.

Due to reduced demand, the production and price of both natural gas and coal are projected to be lower in the *CEF-JL* cases relative to the reference case. The lower prices are due to demand effects only, as there are no *CEF* policies related to technological improvements in fossil fuel supply. The average wellhead price of natural gas in 2020 is expected to be reduced from $3.10 per thousand cubic feet in the reference case to $2.48 and $2.36 per thousand cubic feet in the moderate and advanced cases, respectively. In 2020, the average projected minemouth price of coal is reduced from $12.93 per short ton in the reference case to $12.78 and $11.51 per short ton in the *CEF-JL* moderate and advanced cases, respectively. Because oil prices are assumed to be set on world markets, the average crude oil price is not expected to change. In 2020, average electricity prices are expected to be lower in the *CEF-JL* moderate case, 6.0 cents per kilowatthour compared with 6.1 cents per kilowatthour in the reference case, due to the lower price of fossil fuels, but are higher in the *CEF-JL* advanced case, reaching 6.6 cents per kilowatthour, due to the impact of the $50 carbon fee. As a result of lower energy consumption and generally lower prices, energy expenditures are projected to be lower than in the reference case.

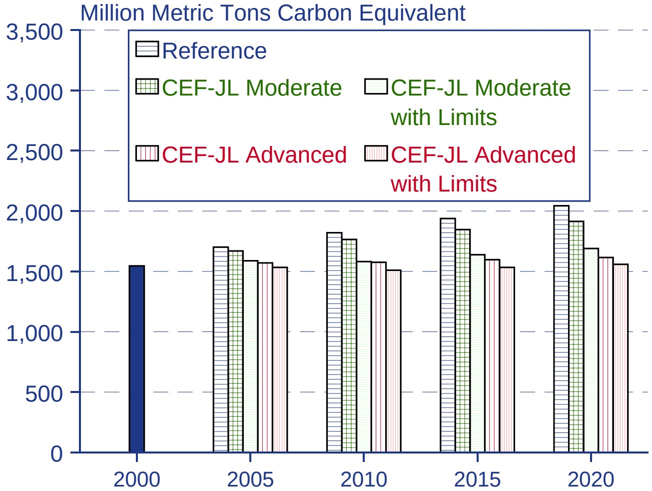
Total projected CO_2 emissions in 2020 are reduced by 130 and 429 million metric tons carbon equivalent, or 6 and 21 percent, in the *CEF-JL* moderate and advanced cases, respectively, due to the lower demand for fossil fuels (Figure 23). Emissions of SO_2, NO_x, and Hg by electricity generators are also generally reduced due to lower projected coal consumption and, in the advanced case, to the policy to reduce particulate emissions (Figures 24 through 26).

With the addition of the emissions limits to the *CEF-JL* cases, primary energy consumption in 2020 is projected to be reduced by 3 percent in the moderate case and 1 percent in the advanced case. In the *CEF-JL* moderate case, the projected decline in energy intensity accelerates from 1.9 percent to 2.0 percent when the emissions limits are added; however, the decline is projected to remain 2.4 percent in the *CEF-JL* advanced case even with the imposition of the emissions limits. Because the *CEF-JL* advanced case already includes a $50 carbon fee, there is little additional reduction in energy demand in that case due to emissions limits on electricity generators, and energy expenditures are similar. In the *CEF-JL* moderate case, higher projected prices for coal, natural gas, and electricity are projected to reduce energy consumption in the residential and commercial sectors when emissions limits are imposed and raise energy expenditures. In the industrial sector, projected energy consumption in 2020 is essentially unchanged because higher demand for natural gas for cogeneration offsets lower demand for purchased electricity. Total projected electricity sales in 2020 are reduced by 7 percent in the *CEF-JL* moderate case when the emissions limits are imposed but is essentially unchanged in the advanced case with the addition of the emissions limits.

In the electricity generation sector, coal-fired generation in 2020 is projected to be reduced by 44 and 19 percent in the moderate and advanced cases, respectively, with the addition of the emissions limits. The impact is less in the advanced case because the advanced case without the limits already includes a $50 carbon fee and particulate reductions. Generation by natural gas, nuclear power, and renewable sources is increased in both cases when the emissions limits are imposed because the limits raise the cost of coal generation.

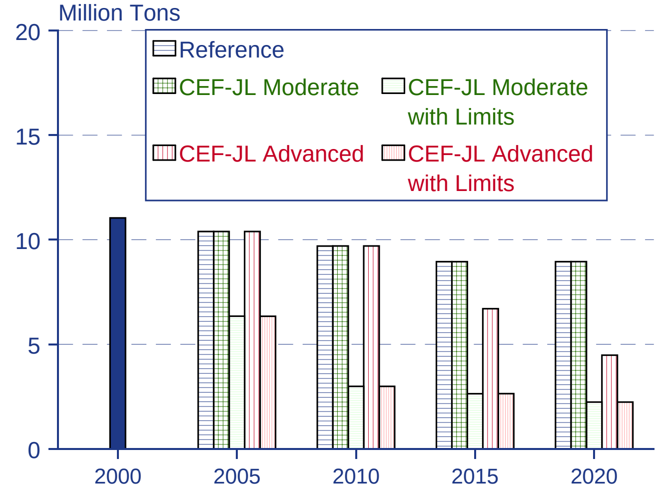
In 2020, total natural gas consumption is projected to be higher by 8 and 4 percent in the *CEF-JL* moderate and advanced cases with the emissions limits, relative to the cases without limits, due primarily to increased natural gas generation and, in the moderate case, to higher cogeneration in the commercial and industrial sectors. As a result, natural gas wellhead prices are projected to be higher by 14 and 11 percent, as production increases to meet demand. Renewable sources of energy are also higher as they become more economical for generation with the emissions limits. Total projected coal consumption is lower by 39 and 16 percent in the moderate and advanced cases with emissions limits, as compared with the respective cases without limits, due to reduced coal-fired generation. Projected petroleum consumption remains unchanged because the emissions limits have a negligible impact on petroleum markets.

Figure 23. Carbon Dioxide Emissions in Five Cases, 2000-2020



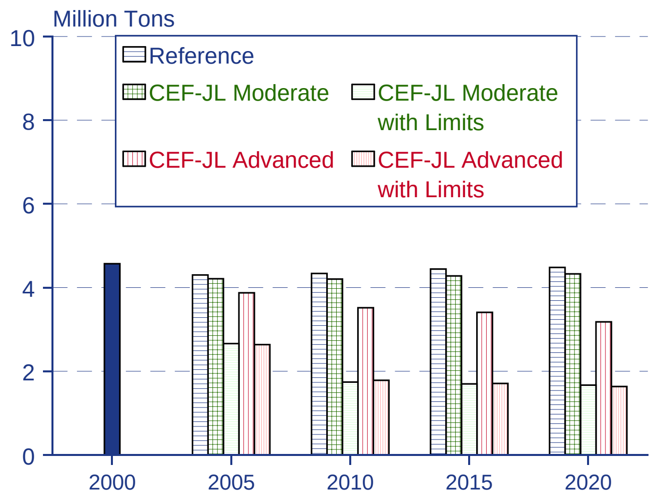
Source: National Energy Modeling System, runs SCENABS.D080301A, SCENCBS.D080301A, SCENCEM.D081601A, SCENDBS.D092601B, and SCENDEMR.D092701A.

Figure 24. Sulfur Dioxide Emissions from Generating Units (Excluding Cogenerators) in Five Cases, 2000-2020



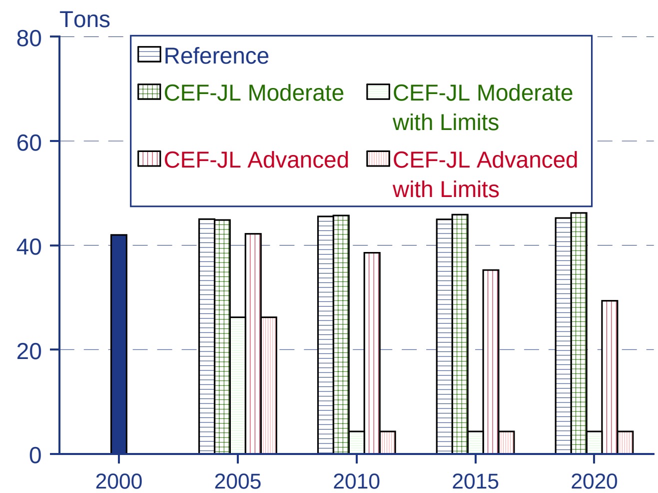
Source: National Energy Modeling System, runs SCENABS.D080301A, SCENCBS.D080301A, SCENCEM.D081601A, SCENDBS.D092601B, and SCENDEMR.D092701A.

Figure 25. Nitrogen Oxides Emissions from Generating Units (Excluding Cogenerators) in Five Cases, 2000-2020



Source: National Energy Modeling System, runs SCENABS.D080301A, SCENCBS.D080301A, SCENCEM.D081601A, SCENDBS.D092601B, and SCENDEMR.D092701A.

Figure 26. Mercury Emissions from Generating Units (Excluding Cogenerators) in Five Cases, 2000-2020



Source: National Energy Modeling System, runs SCENABS.D080301A, SCENCBS.D080301A, SCENCEM.D081601A, SCENDBS.D092601B, and SCENDEMR.D092701A.

Average delivered electricity prices are expected to be higher in 2020 in the *CEF-JL* moderate case when emissions limits are imposed, 7.2 cents per kilowatthour compared with 6.0 cents per kilowatthour. The cost to electricity generators of meeting the emissions limits by installing emissions control equipment or purchasing emissions permits is included in the price of electricity, to the extent to which these costs can be passed through to consumers. CO_2 emissions permit costs are effectively included in the price of the fossil fuel to electricity generators. For the other three emissions, the permit costs are included in the electricity price based on the cost incurred by the marginal generator. However, projected electricity prices remain unchanged in the advanced case with emissions limits in 2020 in part due to lower SO_2 allowance costs. The cost of allowance permits for SO_2 in 2020 is projected to be higher in the moderate case with emissions limits due to the cost of additional emission control equipment constructed to reduce both SO_2 and Hg emissions. However, the permit cost is projected to be lower in the advanced case with emissions limits, compared to the case without limits, because limits on CO_2 emissions lower coal use and reduce the need to switch to lower-sulfur coal or natural gas or install scrubbers.

The projected costs for NO_x permits decrease to zero by 2020 in the *CEF-JL* advanced case with emissions limits as actions taken to reduce CO_2 emissions result in NO_x emissions within the limits. The projected allowance costs for Hg emissions reach $468 and $391 million per ton in 2020, in the *CEF-JL* moderate and advanced cases with emissions limits, reflecting the cost of adding emission control equipment. Allowance costs for CO_2 are projected to be $68 and $50 per metric ton carbon equivalent in the moderate and advanced cases with emissions limits, respectively. In the advanced case with the emissions limits, the CO_2 allowance cost is essentially the same as in the advanced case without the limits.

Between 2001 and 2020, the cumulative incremental resource costs to electricity generators to comply with the emissions limits are $162 billion and $129 billion in the moderate and advanced cases, respectively— 9- and 8-percent increases relative to the cases without emissions limits. The lower additional costs of compliance in the advanced case are due to lower electricity demand in the advanced case, the availability of more efficient generating technologies, and the lower SO_2 emissions as a result of the particulate reduction policy assumed in the advanced case without emissions limits.

Total projected CO_2 emissions in 2020 are reduced by 224 and 57 million metric tons carbon equivalent, or 12 and 4 percent, in the *CEF-JL* moderate and advanced cases with emissions limits, respectively, compared to the cases without the limits, primarily due to lower coal generation. The smaller reduction in the *CEF-JL* advanced case with emissions limits is due to the $50 carbon fee assumed in the *CEF-JL* advanced case without limits, which provides most of the reduction in CO_2.

Residential

The *CEF* study presented eight general categories of polices to remove barriers to technology adoption and reduce energy costs, energy use, and CO_2 emissions in both residential and commercial buildings. Residential sector energy and CO_2 reductions were attributed to equipment standards, voluntary programs, tax credits, building codes, and research and development programs.

The analysis of the programs was conducted through a detailed spreadsheet analysis for both the moderate and advanced cases. The projections in the spreadsheet analysis were then matched in *CEF*-NEMS through changes to consumer hurdle rates, technology costs, and growth trends for each end use. The changes reportedly "reflect the effect of a variety of non-energy-price policies that eliminate many of the barriers to investing in cost-effective efficiency technologies."[33] The *CEF-JL* moderate and advanced cases include many changes to the reference case, including future appliance standards, lower growth rates for miscellaneous electric devices, lower costs for high efficiency appliances, lower consumer hurdle rates, and increases in building shell efficiency. The implementation of each of these changes and its impact on the reference case is described below.

CEF Residential Appliance Standards

Updates to Federally-mandated appliance standards were a major policy in the *CEF* study. In the *CEF* moderate and advanced cases, the standards credited with savings are listed in Table 15.

For the implementation of the *CEF* standards in the *AEO2001* version of NEMS, changes were made to conform to the standards that were announced in January 2001 and, in the case of central air conditioners and heat pumps, subsequently revised by the Bush Administration. The 2010 standards for room air conditioners and refrigerators have not been announced and therefore are not included in the reference case, but are included for the *CEF-JL* cases. The standards implemented in NEMS for these two cases are shown in Table 16.

The refrigerator standard represents about a 12-percent decline in the amount of electricity used per unit relative

[33]Interlaboratory Working Group, *Scenarios for a Clean Energy Future*, ORNL/CON-476 and LBNL-44029 (Oak Ridge National Laboratory, Oak Ridge, TN, and Lawrence Berkeley National Laboratory, Berkeley, CA, November 2000), web site www.ornl.gov/ORNL/Energy_Eff/CEFOnep.pdf.

to the current standard. The room air conditioner standard represents about an 8-percent increase in efficiency over the current standard. All of the other standards are included in the reference case because these standards have been approved since *AEO99*, thus there are no additional energy savings in the *CEF-JL* moderate and advanced cases due to these standards.

CEF Residential Miscellaneous Electricity Growth Rates

The reduction in the growth rates for miscellaneous electric appliances incorporated in the *CEF* study clearly had the largest impact on projected electricity demand. Miscellaneous electricity uses consist of a variety of smaller end uses not individually identified. Major uses of electricity in the residential sector include space heating, space cooling, water heating, refrigeration, cooking, and lighting. By 2010, nearly 65 percent of the projected electricity savings in the *CEF* moderate case was attained by reducing the demand for miscellaneous electric appliances. These appliances include stereo systems, battery chargers, bread makers, and waterbed heaters, as a few examples. Given the way these appliances are used and the fact that many cannot incorporate increased energy efficiency into their design, for example, the heating elements found in many small cooking products, it is difficult to credit this magnitude of electricity savings from voluntary programs and State market transformation programs, as stated in the *CEF* report. The growth in miscellaneous electricity use is dictated by the increasing saturation of relatively new products into the residential sector. It is unclear how market transformation programs or voluntary programs could reduce the natural acceptance of these new products. Some voluntary programs, such as the effort to convince manufacturers to produce electronic equipment with no more than 1 watt of standby power, can have some effect on these growth rates. The standby power, however, contributes less in terms of the increased electricity growth than the active power, thus the growth rates would likely not be affected as much as the *CEF* study claims.

By incorporating the *CEF* assumptions for the moderate and advanced cases, projected electricity use for electronics, the fastest growing component of miscellaneous electricity use, is reduced by 22 and 24 percent in 2010, respectively, relative to the reference case. The reductions in 2020 for the moderate and advanced cases are 55 and 82 percent, respectively, effectively negating any growth in miscellaneous electricity consumption from 2000 to 2020 in the advanced case. From 1990 to 1997, EIA data indicate that miscellaneous electricity use per household increased 70 percent.[34] Given the historical growth for miscellaneous electricity use, it is improbable that efficiency gains could be achieved that would nearly stop all growth in electricity consumption for these appliances over the next 20 years. Table 17 details the percentage reduction in miscellaneous electricity

Table 15. Residential Appliance Efficiency Standards Credited with Savings in *CEF*

Appliance	Standard	Year Implemented
Central Air Conditioners and Heat Pumps	13 SEER	2006
Room Air Conditioners	10.5 EER	2010
Clothes Washers	Horizontal Axis, 1.26 MEF	2006
Natural Gas Hot Water Heaters	0.60 EF	2004
Electric Hot Water Heaters	0.95 EF	2004
Refrigerators (Advanced Case Only)	421 kilowatthours per year	2010

Note: EF is energy factor (Btu out per Btu in); SEER is seasonal energy efficiency ratio (Btu out per watthour in); MEF is modified energy factor (cubic foot per kilowatthour per cycle); EER is energy efficiency ratio (Btu out per watthour in).
Source: Energy Information Administration, Office of Integrated Analysis and Forecasting.

Table 16. Residential Appliance Efficiency Implemented in *CEF-JL* Moderate and Advanced Cases

Appliance	Standard	Year Implemented	Comments
Central Air Conditioners and Heat Pumps	12 SEER	2006	January 2001 standard, revised by Bush Administration
Room Air Conditioners	10.5 EER	2010	*CEF* policy
Clothes Washers (First Tier)	1.04 MEF	2004	January 2001 standard
Clothes Washers (Second Tier)	Horizontal Axis, 1.26 MEF	2007	January 2001 standard
Natural Gas Hot Water Heaters	0.59 EF	2004	January 2001 standard
Electric Hot Water Heaters	0.90 EF	2004	January 2001 standard
Refrigerators (Advanced Case Only)	421 kilowatthours per year	2010	*CEF* policy

Note: EF is energy factor (Btu out per Btu in); SEER is seasonal energy efficiency ratio (Btu out per watthour in); MEF is modified energy factor (cubic foot per kilowatthour per cycle); EER is energy efficiency ratio (Btu out per watthour in).
Source: Energy Information Administration, Office of Integrated Analysis and Forecasting.

[34] Energy Information Administration, Residential Energy Consumption Survey 1990 and 1997, DOE/EIA-0321.

uses in the moderate and advanced cases, relative to the reference case.

CEF Residential Consumer Hurdle Rates

In the reference case, consumer hurdle rates, or the willingness to invest in energy efficiency, vary by appliance type and accordingly influence the efficiency level in a given year for a given appliance. The hurdle rates used in NEMS represent all of the observed and unobserved factors that bring about the average level of efficiency for each major appliance purchased in the marketplace. Although discount rates are defined as a financial premium on investments, the hurdle rates observed in the marketplace are influenced mostly by nonfinancial factors. For example, consumers tend to value an ice maker or other features of a refrigerator more than the expected annual cost to run the appliance over a given time period. Since refrigerators with these features generally use more electricity than those without them, the observed market hurdle rate appears high. For most products, energy efficiency plays a small role in the decisionmaking process for purchasing new appliances, causing large observed hurdle rates.

Estimates for consumer hurdle rates are based on shipment data, which reveal the average purchased efficiency for various appliances on a yearly basis. These data, coupled with cost and performance estimates for these appliances, allow for estimates of consumer hurdle rates. Since the reasons for purchasing equipment of various efficiency levels are not fully known, all of the factors that relate to consumer choice are bundled into the hurdle rate.

In the NEMS residential module, these estimated consumer hurdle rates range from 15 to over 100 percent, depending on the appliance, reflecting the importance of nonfinancial features in appliance purchases. In the *CEF* moderate and advanced cases, consumer hurdle rates for all major appliances were assumed to be 15 percent. This assumption essentially means that all nonfinancial factors were removed from the decisionmaking process. Since many of these purchases are financed through credit card accounts with rates above 15 percent and since many purchases are made by building owners or builders who do not pay the energy bill, this assumption seems very optimistic. By setting the consumer hurdle rates to 15 percent, more rapid adoption of the more efficient technologies was projected in the moderate and advanced cases in *CEF*, especially when coupled with the changes in the costs of the technologies described below. For the *CEF-JL* cases, the *CEF* hurdle rates are used.

Table 17. Reductions in Residential Miscellaneous Electricity Use in the *CEF* Moderate and Advanced Cases, Relative to the Reference Case, 2010 and 2020
(Percent)

Use	*CEF* Moderate Case		*CEF* Advanced Case	
	2010	2020	2010	2020
Electronics	22	55	24	82
Heating Elements. .	8	11	8	11
Motors	9	19	9	22
Lighting	1	10	10	56
Color Televisions . .	8	17	8	25
Furnace Fans.	0	8	2	26

Source: Energy Information Administration, Office of Integrated Analysis and Forecasting.

CEF Technology Costs for Efficient Residential Equipment

In the *CEF* moderate and advanced cases, numerous changes were made to the costs, efficiencies, and the dates of availability for most technologies in the *AEO99* reference case. For some appliances, the cost of the most efficient unit available for purchase was reduced to equal the cost of the least efficient unit. For example, in the *CEF* advanced case, a central air conditioner with a 70 percent greater efficiency than the least efficient unit was offered at the same price as the least efficient unit from 2011 through 2020. It seems highly unlikely that increases in research and development funding or the success of voluntary programs could bring about this change in the relative prices of various appliances in such a short time span considering the need to obtain additional Federal funding, conduct successful research and development, and achieve market acceptance. In the advanced technology case, which assumes greater adoption of more efficient technologies, the cost of a unit with similar efficiency characteristics costs nearly 30 percent more than in the *CEF* advanced case. In the EIA implementation of the *CEF* cost and efficiency characteristics for the *CEF-JL* cases, the same values are used for each case as in the *CEF* analysis. Table 18 shows some of the costs and efficiencies of various residential appliances across the four cases in this report.

Given the costs assumed in the *CEF* study, there are no cost increases to the consumer for the most efficient products. The *AEO2001* best available technology case, which assumes the purchase of only the most efficient technology available throughout the projection period, forecasts a similar level of demand as in the *CEF* advanced case.[35] To attain this lower level of demand, the *AEO2001* best available technology case requires a

[35]Energy Information Administration, *Annual Energy Outlook 2001*, DOE/EIA-0383(2001)(Washington, DC, December 2000), pp. 216-217. Because energy investments for shell improvements are not computable, energy savings from these improvements have been removed from the best available technology case to allow for a comparison of the best available technology case in *AEO2001* and the *CEF* advanced case.

projected cumulative incremental investment by residential consumers of $179 billion through 2010 and of $355 billion through 2020. The *CEF* advanced case, however, projected a cumulative incremental investment of only $15 billion through 2010 and $47 billion through 2020 due to assumptions about lower costs for the most efficient technologies available, due to research and development and State and voluntary programs. This represented a dramatic difference in the costs required to save roughly the same amount of energy in the residential sector.

CEF Changes for Residential Building Shell Efficiency

The final set of changes implemented in the *CEF* study involved policies aimed at increasing the efficiency of building shells. The interaction of many building components, such as windows, insulation, and foundation type, affect the overall efficiency of the structure. Several policies can impact the heating and cooling loads of residential buildings, especially new construction. Stricter building codes, the Energy Star Homes program (ESTAR), tax credits, and the Partnership for the Advancement of Technology in Housing (PATH) are examples of policies which could significantly impact the efficiency and energy consumption for heating and cooling in new houses.

The *CEF* study considered all of the policies listed above in its analysis for both the moderate and advanced cases. The impact of these policies was calculated separately. For the moderate case, it was determined that the *AEO99* reference case projections for shell efficiency improvements in new houses were sufficiently represented for the amount of efficiency gain expected from the policies, and no changes were made. In the advanced case, the *CEF* authors assumed that the shell efficiency for new houses would improve 10 percent by 2010 and 30 percent by 2020, relative to the reference case, based on assumptions regarding the effects of tax credits, building codes, and voluntary programs. Relative to the homes built in *AEO99* in 2000, these changes resulted in new homes that were 19 percent more efficient in 2010 and 47 percent more efficient in 2020. This essentially meant that every home built in 2020 would meet the goals of the PATH program, which strives to build homes that are 50 percent more efficient than current code.

The *AEO2001* version of the NEMS residential module allows for a direct implementation of the policies listed above. Several shell efficiency levels, including ESTAR and PATH, are explicitly represented as an economic choice to the consumer, allowing for tax credits and technological learning. The learning function allows the costs for the more efficient and more costly building shells to decline over time, as builders become more familiar with the techniques and equipment required to meet the higher levels of building shell efficiency. In the *CEF-JL* moderate case, no changes are made to any of the shell parameters, since none were made in the *CEF* study. In the *CEF-JL* advanced case, however, tax credits and changes in consumer hurdle rates are applied to the reference case to represent the changes made in the advanced case for the *CEF* study. By implementing these

Table 18. Cost and Efficiency of Various Residential Technologies, 2015
(Costs in 1991 Dollars, Efficiency Given as an Index, Where Least Efficient Unit Available Equals 1.00)

Technology	Reference		Advanced Technology		*CEF-JL* Moderate		*CEF-JL* Advanced	
	Cost	Efficiency	Cost	Efficiency	Cost	Efficiency	Cost	Efficiency
Air-Source Heat Pump (Heating)								
Least Efficient	3,700	1.00	3,700	1.00	3,700	1.00	3,700	1.00
Most Efficient	4,400	1.33	4,400	1.46	4,300	1.33	3,700	1.82
Natural Gas Furnace								
Least Efficient	750	1.00	750	1.00	750	1.00	750	1.00
Most Efficient	900	1.23	900	1.23	680	1.23	750	1.23
Central Air Conditioner								
Least Efficient	1,800	1.00	1,800	1.00	1,800	1.00	1,800	1.00
Most Efficient	2,300	1.50	2,300	1.50	1,800	1.60	1,800	1.70
Electric Hot Water Heater								
Least Efficient	257	1.00	257	1.00	225	1.00	225	1.00
Most Efficient	825	2.89	825	3.11	400	2.44	400	2.44
Natural Gas Hot Water Heater								
Least Efficient	300	1.00	300	1.00	190	1.00	190	1.00
Most Efficient	1,500	1.46	1,500	2.37	1,500	1.46	225	1.46
Refrigerators[a]								
Least Efficient	480	1.00	480	1.00	480	1.00	480	1.00
Most Efficient	700	0.84	700	0.63	480	0.52	480	0.36

[a]Refrigerator efficiency index given in terms of electricity use per unit. As the value decreases, the efficiency of the unit increases.
Source: Energy Information Administration, Office of Integrated Analysis and Forecasting.

changes, homes built in 2010 are projected to be 15 percent more efficient relative to new homes built in 2000, while those built in 2020 are projected to be 19 percent more efficient. Thus, the *CEF-JL* advanced case projects only a slightly lower efficiency improvement in 2010 compared to the advanced case in the *CEF* analysis, but a much lower efficiency improvement, less than half, in 2020 based on the same shell efficiency assumptions.

Impact of *CEF* Policies on Residential Demand

Given the extensive data and modeling changes needed to replicate the *CEF* cases, the *CEF-JL* moderate and advanced cases have significant changes in residential energy demand, relative to the reference case. Delivered energy consumption in 2010 is projected to be lower by 2 and 6 percent in the *CEF-JL* moderate and advanced cases, respectively, relative to the reference case, as increased efficiency, changes in consumer behavior, and the $50 carbon fee in the advanced case significantly reduce the amount of energy, particularly electricity, needed to power appliances (Table 19). In 2020, the relative reductions in projected residential consumption in the *CEF-JL* moderate and advanced cases are 7 and 14 percent.

As noted above, the assumed reduction in the growth of miscellaneous electric devices in the *CEF-JL* cases has the largest impact on projected energy consumption. By 2020, projected electricity consumption is reduced by 16 and 26 percent in the *CEF-JL* moderate and advanced cases, respectively, relative to the reference case. Residential CO_2 emissions are projected to decrease by 35 and 111 million metric tons carbon equivalent, or 9 and 29 percent, in 2020 in the *CEF-JL* moderate and advanced cases, respectively, compared to the reference case.

Impact of Emissions Limits on Residential Demand in the *CEF-JL* Cases

Due to the lower level of projected energy demand in the *CEF-JL* moderate and advanced cases, relative to the other cases, the impact of emissions limits on energy

Table 19. Residential Sector Projections in the *CEF-JL* Moderate and Advanced Cases, 2010 and 2020

Projections	1999	Reference	*CEF-JL* Moderate: Without Emissions Limits	*CEF-JL* Moderate: With Emissions Limits	*CEF-JL* Advanced: Without Emissions Limits	*CEF-JL* Advanced: With Emissions Limits
				2010		
Delivered Energy Consumption (Quadrillion Btu)	**10.7**	**12.2**	**11.9**	**11.6**	**11.4**	**11.3**
Electricity	3.9	4.9	4.6	4.4	4.4	4.3
Natural Gas	4.9	5.5	5.5	5.4	5.4	5.3
Petroleum	1.4	1.3	1.3	1.3	1.2	1.2
Delivered Prices (1999 Dollars per Million Btu)	**13.18**	**13.41**	**12.80**	**14.17**	**13.32**	**13.85**
Electricity	23.69	22.19	21.52	24.81	23.31	24.02
Natural Gas	6.52	6.70	6.39	6.81	6.26	6.69
Petroleum	7.55	9.37	9.36	9.27	8.95	9.10
Effective Delivered Prices[a] (1999 Dollars per Million Btu)	**13.18**	**13.41**	**12.80**	**14.17**	**13.78**	**14.31**
Electricity	23.69	22.19	21.52	24.81	23.31	24.02
Natural Gas	6.52	6.70	6.39	6.81	6.98	7.41
Petroleum	7.55	9.37	9.36	9.27	9.89	10.04
CO_2 Emissions (Million Metric Tons Carbon Equivalent)	**290**	**346**	**333**	**267**	**285**	**262**
				2020		
Delivered Energy Consumption (Quadrillion Btu)	**10.7**	**13.5**	**12.6**	**12.2**	**11.6**	**11.5**
Electricity	3.9	5.7	4.8	4.5	4.2	4.2
Natural Gas	4.9	6.1	6.1	6.0	5.8	5.7
Petroleum	1.4	1.2	1.2	1.2	1.1	1.1
Delivered Prices (1999 Dollars per Million Btu)	**13.18**	**13.62**	**12.74**	**13.88**	**12.98**	**13.20**
Electricity	23.69	22.16	22.32	25.20	24.00	24.06
Natural Gas	6.52	6.56	5.98	6.32	5.88	6.15
Petroleum	7.55	9.47	9.38	9.26	9.02	9.07
Effective Delivered Prices[a] (1999 Dollars per Million Btu)	**13.18**	**13.62**	**12.74**	**13.88**	**13.46**	**13.67**
Electricity	23.69	22.16	22.32	25.20	24.00	24.06
Natural Gas	6.52	6.56	5.98	6.32	6.59	6.87
Petroleum	7.55	9.47	9.38	9.26	9.96	10.01
CO_2 Emissions (Million Metric Tons Carbon Equivalent)	**290**	**383**	**348**	**271**	**272**	**254**

[a]Effective delivered price reflects the cost impact of CO_2 emission allowances in cases that include a CO_2 limit.

Source: National Energy Modeling System, runs SCENABS.D080301A, SCENCBS.D080301A, SCENCEM.D081601A, SCENDBS.D092601B, and SCENDEMR.D092701A.

prices is relatively small (Figure 27). In 2020, the imposition of emissions limits in the *CEF-JL* advanced case has relatively little impact on projected residential energy prices, as electricity generators meet the emissions limits with relative ease. In 2010, however, residential electricity prices are projected to increase by 15 percent in the *CEF-JL* moderate case and 3 percent in the *CEF-JL* advanced case when the emissions limits are imposed, due in part to the short lead-time allowed for the more efficient equipment to enter into the stock.

In all cases, if the emissions limits on electricity generators cause projected electricity prices to increase, projected consumption of electricity by the residential sector decreases. In 2010, due to the increase in the projected price of electricity when the limits are imposed, electricity consumption is projected to be lower by 5 percent in the *CEF-JL* moderate case and by 1 percent in the *CEF-JL* advanced case. In 2020, the comparable reduction in projected electricity consumption is 5 percent in the *CEF-JL* moderate case. In 2020, projected electricity consumption is the same in the *CEF-JL* advanced case when the emissions limits are imposed on electricity generators because electricity prices are very similar. In 2020, projected CO_2 emissions from the residential sector are reduced by 77 and 18 million metric tons carbon equivalent, or 22 and 7 percent, in the *CEF-JL* moderate and advanced cases with the emissions limits, compared to the cases without the limits, primarily due to reductions in electricity consumption.

Commercial

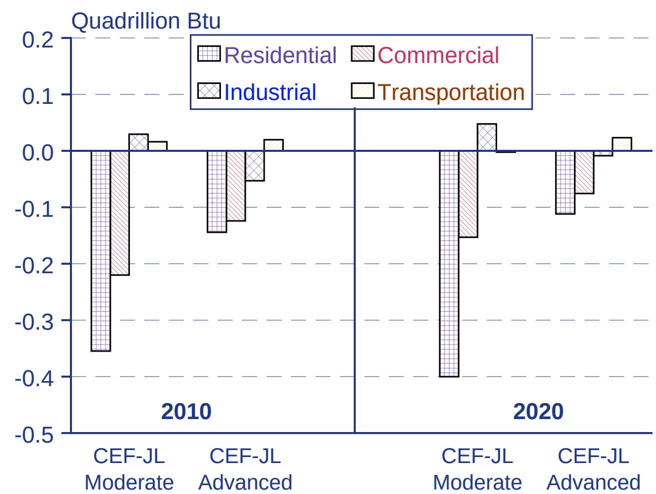
Commercial sector energy and CO_2 savings reported in the *CEF* study were attributed to five categories of policies, equipment standards, commercial building codes, voluntary programs, research and development programs, and a utility program featuring heat pump water heaters. Similar to the residential sector, in the *CEF* study these programs were analyzed separately, and the results were then incorporated into *CEF*-NEMS, through lower growth rates for miscellaneous electric devices, lower costs for high efficiency appliances, lower consumer hurdle rates, and efficiency increases for miscellaneous uses of natural gas. For this study, the changes for the *CEF* policies were implemented in the same manner as in the *CEF* study, as described below.

CEF Commercial Appliance Standards

Updates to Federally-mandated commercial appliance standards accounted for 31 and 28 percent of projected commercial energy savings in 2010 for the moderate and advanced cases in the *CEF* study, respectively. The standards credited with savings in these cases are listed in Table 20.

The purpose of a standard is to mandate a minimum efficiency level for a particular class of equipment. After the date that a standard becomes effective, manufacturers can no longer make equipment that does not meet the level of efficiency mandated by the standard. Although represented as standards in the separate *CEF* analysis, the items in Table 20 were not strictly implemented as standards in *CEF*-NEMS. Specifically, heating, cooling, and lighting technologies meeting the standard levels were made available in the appropriate years; however, models of equipment that did not meet the mandated efficiency levels were allowed to remain

Figure 27. Impact of Emissions Limits on Delivered Energy Consumption in Two Cases, 2010 and 2020



Source: National Energy Modeling System, runs SCENCBS.D080301A, SCENCEM.D081601A, SCENDBS.D092601B, and SCENDEMR.D092701A.

Table 20. Commercial Appliance Efficiency Standards Credited with Savings in *CEF*

Appliance	Standard	Year Implemented
Packaged Air Conditioners	10.3 EER	2005
Packaged Air Conditioners (Advanced Case Only)	11 EER	2010
Natural Gas Furnace and Boiler (Advanced Case Only)	0.82 combustion efficiency	2010
Fluorescent Ballasts	Electronic	2004
Transformer Standard (Advanced Case Only)	65 kilowatthours per year	2004

Note: EER is energy efficiency ratio (Btu out per watthour in).
Source: Energy Information Administration, Office of Integrated Analysis and Forecasting.

on the market through 2020. The transformer standard was not implemented in *CEF*-NEMS because transformers are not explicitly represented.

Table 21 shows the updated commercial standards represented in the *CEF-JL* moderate and advanced cases. Changes were made to the *CEF* study assumptions to conform to the fluorescent ballast standard announced by the Department of Energy (DOE) in September 2000 and additional standards that were announced by DOE in January 2001. The standards announced by DOE are represented as true standards in the *CEF-JL* cases and in the reference case, i.e., only equipment that meets the standard is available for purchase after its effective date. The standards for air-cooled packaged air conditioners and the 2010 standard for natural-gas-fired furnaces and boilers have not been announced and therefore are not included in the reference case but are implemented in the *CEF-JL* cases as in the *CEF* analysis.

The 2005 packaged air conditioner standard represents about a 16-percent increase in efficiency over the current standard. The 2010 packaged air conditioner standard and the natural gas furnace and boiler standard in the advanced case represent about 23.6 and 2.5-percent increases in efficiency, respectively, relative to the current standard. These standards were implemented as in the *CEF* study, so that models of equipment with efficiency ratings that do not meet the reported standard remain available through 2020. Since the transformer standard was not implemented in the advanced case in the *CEF* study because transformers are not explicitly represented, the same is done in this study. All of the other standards are included in the reference case, thus there are no additional energy savings in the moderate or advanced cases due to these standards.

CEF Commercial Miscellaneous Electricity Growth Rates

Adjustments regarding the amount of electricity used by miscellaneous commercial applications in the *CEF* study had a significant impact on projected electricity demand. Miscellaneous energy uses consist of a variety of smaller end uses not individually identified. In the commercial sector, major uses of energy include space heating, space cooling, water heating, refrigeration, cooking, lighting, ventilation, and office equipment. Miscellaneous uses include all other uses, such as telecommunications and medical equipment, exit signs, transformers, and automated teller machines. By 2010, 58 percent of the projected commercial electricity savings in the *CEF* moderate case was achieved by reducing miscellaneous electricity demand. The miscellaneous electricity savings in the *CEF* study were attributed strictly to voluntary programs in the moderate case, specifically Energy Star exit signs, transformers, and traffic lights. Savings in the *CEF* advanced case were attributed to a 2004 transformer standard in addition to the Energy Star programs although the standard was not implemented in *CEF*-NEMS.

It is difficult to credit this magnitude of electricity savings from voluntary programs given the variety of uses for electricity in this category, such as telecommunications equipment, automated teller machines, and medical equipment. Although there is the potential for some efficiency improvements, it is unlikely that efficiencies could improve enough to reach the consumption levels achieved in *CEF*. In addition, the incremental cost for energy-efficient equipment can be substantial. For example, TP 1/Energy Star transformers are readily available from several major manufacturers; however,

Table 21. Commercial Appliance Efficiency Implemented in *CEF-JL* Moderate and Advanced Cases

Appliance	Standard	Year Implemented	Comments
Packaged Air Conditioners	10.3 SEER	2005	Implemented in *CEF-JL* moderate and advanced cases, identical to implementation in *CEF* study
Packaged Air Conditioners	11 SEER	2010	Implemented in *CEF-JL* advanced case, identical to implementation in *CEF* study
Natural Gas Furnace	0.75 percent casing loss	2003	Implemented in *CEF-JL* moderate and advanced cases and in reference case, announced by DOE in January 2001, not included in *CEF* study
Natural Gas Furnace and Boiler	0.82 combustion efficiency	2010	Implemented in *CEF-JL* advanced case, identical to implementation in *CEF* study
Natural Gas Water Heater	0.80 TE	2003	Implemented in *CEF-JL* moderate and advanced cases and in reference case, announced by DOE in January 2001, not included in *CEF* study
Fluorescent Ballasts	Electronic	2005	Implemented in *CEF-JL* moderate and advanced cases and in reference case, announced by DOE in September 2000, implemented one year later than in *CEF* study

Note: SEER is seasonal energy efficiency ratio (Btu out per watthour in); TE is thermal efficiency (Btu out per Btu in).
Source: Energy Information Administration, Office of Integrated Analysis and Forecasting.

cost premiums over conventional models range from 50 to 100 percent, depending on size.[36] The savings estimated for transformers and exit signs were thought to be "particularly important" in the *CEF* study. Although savings were attributed to miscellaneous uses of electricity in the *CEF* study and calculated in the spreadsheet analysis, modifications made to the growth rate of miscellaneous uses in *CEF*-NEMS were not attributed to policies. The *CEF* study stated that "[the] changes are not policy induced . . . . [T]he energy savings from the stand-alone *CEF*-NEMS runs fell short of those in our off-line analysis even after implementing the source code and input file changes . . . ."[37] The penetration rate for "other end uses" of electricity was adjusted ". . . [i]n order to match total forecast electricity savings with our off-line accounting . . . ."[38] The adjustments made to affect the growth rate of miscellaneous electricity use in *CEF*-NEMS are summarized in Table 22. The same adjustments to the penetration rate for "other end uses" of electricity are incorporated for the *CEF-JL* moderate and advanced cases, reducing projected miscellaneous electricity use by 10 percent in 2010, in both cases, relative to the reference case and by 22 and 26 percent, respectively, in 2020.

CEF Commercial Miscellaneous Natural Gas Growth Rates

In addition to adjusting the penetration rate for other uses of electricity, an annual efficiency increase for other natural gas consumption was included in the moderate and advanced cases in the *CEF* analysis to "calibrate energy consumption to [*CEF*] off-line analysis estimates in 2010 and 2020."[39] Again, this change was not attributed to any specific policy. The efficiency of other natural gas consumption was increased 1 percent per year between 2001 and 2010 for both the moderate and advanced cases. The efficiency improvement was increased between 2011 and 2020 to 4 percent per year in the moderate case and 16 percent per year in the advanced case. The increase of 1 percent per year from 2001 through 2010 could be attributed to success of voluntary programs in encouraging the adoption of more efficient natural-gas-fired equipment. However, projecting a 16-percent improvement in efficiency each year for ten years seems extremely optimistic considering the variety of uses included in the category, ranging from electricity generators to commercial laundry equipment to swimming pool heaters, and the slow turnover rate in the stock of most commercial equipment. Nevertheless, the same efficiency improvements in other natural gas consumption are implemented in the *CEF-JL* cases.

Table 22. Adjustments to the Penetration Rate of Commercial Miscellaneous Electricity Use in the *CEF* Moderate and Advanced Cases, Relative to the Reference Case, 2010 and 2020
(Percent)

Use	*CEF* Moderate Case		*CEF* Advanced Case	
	2010	2020	2010	2020
Other End Uses of Electricity	-28	-45	-28	-52

Source: Interlaboratory Working Group, *Scenarios for a Clean Energy Future*, ORNL/CON-476 and LBNL-44029 (Oak Ridge National Laboratory, Oak Ridge, TN, and Lawrence Berkeley National Laboratory, Berkeley, CA, November 2000), Appendix A1, web site www.ornl.gov/ORNL/Energy_Eff/CEF-A1.pdf.

CEF Commercial Consumer Hurdle Rates

In the reference case, a distribution of consumer hurdle rates for each major end-use service represents the willingness of commercial consumers to invest in energy efficiency. Not all consumers will have the same requirements and priorities when purchasing equipment, and in practice, the average hurdle rates observed are often much higher than the cost of borrowing money for a variety of reasons. Limited availability of investment funds and the desire for particular features, such as choosing more product space over more insulation in a refrigerated display case, are examples of reasons for high hurdle rates. The distribution of commercial hurdle rates in the reference case ranges from the 10-year Treasury Bill rate used by the Federal sector when making purchase decisions to a rate that minimizes the installed capital costs of equipment.

In the *CEF* moderate and advanced cases, modifications were made to the hurdle rates for all major commercial end-use services. For several end uses, hurdle rates were reduced to the financial component for 2011 through 2020, eliminating all other aspects, such as transaction and information costs, that factor into a purchase decision. This change reflected "a world in which aggressive programs and policies remove barriers to adoption of energy-efficient technologies through the success of voluntary programs and increased funding for research and development." Additional modifications were

[36] A. Hinge, M. Suozzo, T. Jones, D. Korn, and C. Peverell, *Market Transformation for Dry-Type Distribution Transformers: The Opportunity and the Challenges*, Proceedings of the 2000 ACEEE Summer Study on Energy Efficiency in Buildings / 6.191 (Washington, DC; American Council for an Energy-Efficient Economy, August 2000)

[37] Interlaboratory Working Group, *Scenarios for a Clean Energy Future*, ORNL / CON-476 and LBNL-44029 (Oak Ridge National Laboratory, Oak Ridge, TN, and Lawrence Berkeley National Laboratory, Berkeley, CA, November 2000), Appendix A1, pp. A-1.14 and A-1.16, web site www.ornl.gov / ORNL / Energy_Eff / CEF-A1.pdf.

[38] *Ibid.*

[39] *Ibid.*, p. A-1.13.

made to the share of consumers that could potentially switch technology and/or fuel types when hurdle rate changes were not sufficient to reach the desired energy savings. Space heating, space cooling, and ventilation end uses were all affected to varying degrees by modifications to decision rule shares. Reference case shares are based on the proportions of government, privately owned, and leased space in EIA's Commercial Buildings Energy Consumption Survey and estimates of self-built versus speculative developer space for new construction.

A large part of the savings from the hurdle rate and decision rule changes was attributed to voluntary programs, such as Energy Star buildings and Rebuild America. The *CEF* study credited voluntary programs with 52 percent and 49 percent of 2010 commercial energy savings in the moderate and advanced cases, respectively. Whole building research and development programs were assumed to make other policies, such as voluntary programs, less expensive and therefore increased their penetration. In addition, utility programs for heat pump water heaters were credited with savings in the *CEF* study. Presumably, part of the savings from the changes in hurdle rates was attributed to these programs. Since energy may be a small part of the cost of owning and operating a building and since building owners who do not pay the energy bill make many of the initial purchases, these assumptions seem very optimistic and may not be representative of real markets. In implementing the *CEF* assumptions for the *CEF-JL* cases, however, hurdle rates are set to the values described in the *CEF* study in accordance with the request for this analysis.

CEF Savings for Commercial Building Shell Efficiency

The *CEF* study included a set of policies aimed at increasing the efficiency of building shells. The interaction of many building components, such as windows, insulation, and foundation type, affected the overall efficiency of the structure. Several policies can impact the heating and cooling loads of commercial buildings. A new standard for commercial building codes, the Energy Star Buildings and Rebuild America programs, and whole building research and development for new buildings were all policies which could significantly impact the efficiency and energy consumption for heating and cooling in commercial buildings.

The *CEF* study considered all of the policies listed above in its analysis for both the moderate and advanced cases. The impact of these policies was calculated separately, since the *AEO99* version of NEMS did not allow a direct method of implementing the prescribed policies. No changes were made to the *AEO99* reference case projections to incorporate additional commercial building shell efficiency improvements credited with savings in the *CEF* moderate and advanced cases. Presumably, part of the savings from the hurdle rate and decision rule changes was attributed to increased building shell efficiency through adoption of new building codes and the success of the programs specified above. Because no specific changes in commercial building shell efficiency were implemented in *CEF*-NEMS, no specific changes are implemented in the *CEF-JL* cases.

Impact of *CEF* Policies on Commercial Demand

In the *CEF-JL* moderate and advanced cases, commercial delivered energy consumption is projected to be 4 and 5 percent lower in 2010, respectively, relative to the reference case, and 8 and 11 percent lower in 2020 (Table 23). Reduced demand for electricity is projected to account for 86 percent of the 2010 energy savings in the moderate case and 79 percent in the advanced case. In 2020, the projected savings attributed to electricity demand are 88 and 80 percent in the moderate and advanced cases. Changes in consumer behavior and a reduction in the growth of miscellaneous uses of electricity are projected to provide the most significant impact on commercial energy use and resulting commercial sector CO_2 emissions in both cases because few changes are assumed for commercial equipment efficiency for the *CEF-JL* cases. The $50 carbon fee in the advanced case has an additional impact.

Projected demand for purchased electricity is further reduced by 2020 due to increased adoption of distributed generation technologies. The commercial sector is projected to generate an additional 0.8 and 2.5 billion kilowatthours of electricity in 2020 (6 and 19 percent) in the moderate and advanced *CEF-JL* cases, respectively, compared to the reference case. This result is a departure from the *CEF* study because distributed generation in the commercial sector was not represented in the *AEO99* version of NEMS that was the basis of the *CEF* study. The projected reductions in CO_2 emissions attributable to the commercial sector in 2020 are 31 and 86 million metric tons carbon equivalent, or 9 and 25 percent, for the moderate and advanced cases, respectively, relative to the reference case.

Impact of Emissions Limits on Commercial Demand in the *CEF-JL* Cases

The introduction of emissions limits is projected to have a larger impact on commercial electricity prices, and hence, electricity use and CO_2 emissions in the moderate case than in the advanced case. Small additional savings are achieved when the emissions limits are applied to the advanced case, which assumes a carbon fee even without the emissions limits. In the advanced *CEF-JL* case with emissions limits, CO_2 emissions associated with commercial energy use are projected to be lower by 23 and 21 million metric tons carbon equivalent (9 and 8 percent) in 2010 and 2020, respectively, relative to the same case without emissions limits. The larger projected price increase that occurs in the moderate *CEF-JL* case with emissions limits results in projected reductions in CO_2 emissions of 62 and 74 million metric tons carbon equivalent, or 21 and 23 percent, in 2010 and 2020, respectively, due to the price increase caused by the emissions limits. Increased use of distributed generation is a major factor in reducing purchased electricity demand in the moderate *CEF-JL* case with emissions limits, with an additional 1.3 and 19.1 billion kilowatt-hours (17 and 134 percent) of electricity generation projected in 2010 and 2020, respectively.

Industrial

In the industrial sector, six categories of policies were included in the *CEF* study:

- Voluntary industrial sector agreements
- Voluntary programs, e.g., Motor Challenge
- Information programs, e.g., expanding the number of industrial assessment centers
- Investment enabling programs, e.g., tax incentives
- Regulations, e.g., motor standards
- Research and development programs.

For these policies, the advanced case differed from the moderate case only in terms of the scope or magnitude. The moderate case assumed an approximate 50 percent increase in funding from existing levels for the policies, and the advanced case assumed an approximate 100 percent increase.[40]

The NEMS industrial demand module divides each subsector into three components: buildings, boilers-steam-cogeneration, and process and assembly. The *CEF* authors represented the impacts of the programs and

Table 23. Commercial Sector Projections in the *CEF-JL* Moderate and Advanced Cases, 2010 and 2020

Projections	1999	Reference	*CEF-JL* Moderate: Without Emissions Limits	*CEF-JL* Moderate: With Emissions Limits	*CEF-JL* Advanced: Without Emissions Limits	*CEF-JL* Advanced: With Emissions Limits
			2010			
Delivered Energy Consumption (Quadrillion Btu)	**7.6**	**9.9**	**9.5**	**9.2**	**9.4**	**9.2**
Electricity	3.7	4.9	4.6	4.4	4.5	4.5
Natural Gas	3.1	4.2	4.1	4.1	4.1	4.0
Petroleum	0.6	0.6	0.6	0.6	0.6	0.6
Delivered Prices (1999 Dollars per Million Btu)	**13.28**	**12.23**	**11.33**	**13.38**	**12.26**	**12.94**
Electricity	21.64	18.76	17.60	21.65	19.70	20.65
Natural Gas	5.34	5.63	5.32	5.73	5.17	5.59
Petroleum	4.99	6.27	6.25	6.17	5.98	6.05
Effective Delivered Prices[a] (1999 Dollars per Million Btu)	**13.28**	**12.23**	**11.33**	**13.38**	**12.65**	**13.32**
Electricity	21.64	18.76	17.60	21.65	19.70	20.65
Natural Gas	5.34	5.63	5.32	5.73	5.89	6.31
Petroleum	4.99	6.27	6.25	6.17	6.96	7.02
CO_2 Emissions (Million Metric Tons Carbon Equivalent)	**242**	**315**	**298**	**236**	**261**	**238**
			2020			
Delivered Energy Consumption (Quadrillion Btu)	**7.6**	**10.9**	**10.0**	**9.8**	**9.7**	**9.6**
Electricity	3.7	5.6	4.9	4.6	4.7	4.7
Natural Gas	3.1	4.5	4.4	4.4	4.3	4.3
Petroleum	0.6	0.6	0.6	0.6	0.6	0.6
Delivered Prices (1999 Dollars per Million Btu)	**13.28**	**12.55**	**11.66**	**13.28**	**12.43**	**12.62**
Electricity	21.64	18.83	18.41	21.94	20.22	20.31
Natural Gas	5.34	5.67	5.08	5.42	4.95	5.22
Petroleum	4.99	6.37	6.29	6.16	6.15	6.16
Effective Delivered Prices[a] (1999 Dollars per Million Btu)	**13.28**	**12.55**	**11.66**	**13.28**	**12.82**	**13.01**
Electricity	21.64	18.83	18.41	21.94	20.22	20.31
Natural Gas	5.34	5.67	5.08	5.42	5.67	5.94
Petroleum	4.99	6.37	6.29	6.16	7.12	7.13
CO_2 Emissions (Million Metric Tons Carbon Equivalent)	**242**	**347**	**316**	**242**	**261**	**240**

[a]Effective delivered price reflects the cost impact of CO_2 emission allowances in cases that include a CO_2 limit.

Source: National Energy Modeling System, runs SCENABS.D080301A, SCENCBS.D080301A, SCENCEM.D081601A, SCENDBS.D092601B, and SCENDEMR.D092701A.

[40]Interlaboratory Working Group, *Scenarios for a Clean Energy Future*, ORNL/CON-476 and LBNL-44029 (Oak Ridge National Laboratory, Oak Ridge, TN, and Lawrence Berkeley National Laboratory, Berkeley, CA, November 2000), Appendix B-2, web site www.ornl.gov/ORNL/Energy_Eff/CEF-B2.pdf.

policies by five general types of changes made within the industrial sector:

- Boiler efficiencies were increased over time
- Building energy use was decreased over time
- Retirement rates were increased for existing equipment
- Production flows within specific sectors were modified
- Technology possibility curves (TPCs), which represent the rate of change between current energy intensity and energy intensity in 2020, were adjusted to reflect more rapid efficiency improvements over time.

The *CEF* authors indicated which of the five modifications would result from the policies or programs without specifying the detailed impact of each. These five types of changes are described in more detail below.

CEF Industrial Boiler Efficiencies

Several of the policies outlined in *CEF* were assumed by the *CEF* authors to increase boiler efficiencies over time. The most important of these is the Steam Challenge program. This voluntary program is a public-private initiative launched in April 1998 to provide targeted information and technical assistance to help industrial customers retrofit, maintain, and operate their steam systems more efficiently and profitably. State industrial energy efficiency programs and clean air partnerships and increased research and development programs were also expected to increase boiler efficiencies. Table 24 shows the assumed improvement in boiler efficiencies across all industries for the *CEF* moderate and advanced cases resulting from these expanded programs. The same boiler efficiency improvements are implemented in the *CEF-JL* cases. Since average boiler efficiency has changed very little over time, these targets may be overly optimistic.[41]

CEF Industrial Buildings Energy Use

Expansion of voluntary programs, such as ENERGY STAR Buildings and Green Lights programs, and industrial sector agreements were identified in *CEF* as means for improving the efficiency of buildings energy use. Investment enabling programs, including expanded State industrial energy efficiency programs, expanded ESCO / Utility programs, and tax incentives for plant energy managers, were also expected by the *CEF* authors to improve the efficiency of building energy use. Many States currently have industrial energy efficiency programs and ESCO / Utility programs, but many of the latter programs have experienced reduced funding lately. Providing tax incentives for energy managers would be a new program. The individual effect of each program was not identified, but the aggregate improvements in the industrial buildings end uses were modified in *CEF* as shown in Table 25.

These energy efficiency improvements, which are also implemented for the *CEF-JL* cases, were applied equally across all industries. These improvements parallel the assumed increase in commercial buildings efficiency in

Table 24. *CEF* Assumptions for Boiler Efficiencies

Category	Baseline Efficiency (Percent)	*CEF* Moderate (Average Percent Increase per Year)[a]	*CEF* Advanced (Average Percent Increase per Year)[a]	Comment
Petroleum	82	0.2	0.2	Included in *CEF-JL*
Natural Gas	80	0.2	0.3	Included in *CEF-JL*
Coal	81	0.2	0.3	Included in *CEF-JL*
Biomass	74	0.1	0.2	Included in *CEF-JL*

[a]Relative to the reference case.
Source: Energy Information Administration, Office of Integrated Analysis and Forecasting.

Table 25. *CEF* Assumptions for Buildings Efficiencies

Category	*CEF* Moderate (Annual Improvement Factor)[a]	*CEF* Advanced (Annual Improvement Factor)[a]	Comment
Lighting: Electricity	0.9870	0.9864	Included in *CEF-JL*
Heating, Ventilation, Air Conditioning: Electricity	0.9950	0.9837	Included in *CEF-JL*
Heating, Ventilation, Air Conditioning: Natural Gas	0.9850	0.9850	Included in *CEF-JL*
Heating, Ventilation, Air Conditioning: Steam	0.9975	0.9889	Included in *CEF-JL*

[a]Relative to the reference case.
Source: Energy Information Administration, Office of Integrated Analysis and Forecasting.

[41]Energy Information Administration, *NEMS Industrial Model: Modeling Energy Efficiency Standards for Boilers and Motors* (Arthur D. Little, Inc., April 1995), and web site www.oit.doe.gov / factsheets / steam_challenge / pdfs / boiler.pdf.

CEF. Because the buildings component in the industrial model covers office areas in the manufacturing sector, not the manufacturing floor, this is a reasonable assumption.

CEF Industrial Equipment Retirement Rates

Similar to boiler efficiency and buildings energy use improvements, many different programs were assumed by the *CEF* authors to contribute to the acceleration of retirement rates. Expanded voluntary industrial sector agreements, an expanded Motor Challenge program, expanded State industrial energy efficiency programs and Clean Air Partnerships, motor standards and certification, and expanded demonstration programs were all mentioned as accelerating the retirement rates for industrial equipment. The retirement rates, which were the same for both the moderate and advanced cases, are shown in Table 26, along with those included in the reference case. The *CEF* retirement rates are used in the *CEF-JL* cases.

CEF Industrial Production Flow Modifications

In the *CEF* study, production flows for two industries, paper and cement, were modified to reflect the impact of consumer information programs which encourage demand for environmentally benign products. In the paper industry, this program would take the form of labeling recycled / nonbleached paper. As a result of this labeling program, the share of waste pulping was projected to increase by 0.2 percent per year in the *CEF* moderate case and by 0.4 percent per year in the *CEF* advanced case. In the advanced case, the recycled share of pulping input increased to 46 percent, which is not an unreasonable assumption. In order to maintain a reasonable balance of production flows, kraft pulping was projected to decrease by 0.2 percent per year in the *CEF* moderate case and by 0.4 percent per year in the *CEF* advanced case. Bleaching throughput was assumed to decrease by 0.1 percent per year in the *CEF* moderate case and by 0.2 percent in the *CEF* advanced case. The same modifications to production flows in the paper industry are incorporated in the *CEF-JL* cases.

In the cement industry, the *CEF* authors proposed a program promoting the establishment of performance-based cement standards. This program would disseminate information to public and private agencies responsible for cement procurement and specification on the environmental advantages of blended cements. While the use of blended cements may be practical, such a change must be approved by the American Society for Testing and Materials. The *CEF* moderate case assumed that the increased use of blended cements would reduce the use of clinker, which is the raw material used to produce cement, by 6.9 million tons, and the *CEF* advanced case assumed it would reduce the use of clinker by 16.4 million tons. The increased use of blended cements would lead to lower process emissions of CO_2. These process emissions are not modeled in NEMS.

In the steel industry, *CEF* assumed that electric arc furnaces (EAF) would increase their share of production from 40 percent to 55 percent in the advanced case, while the share for basic oxygen furnaces (BOF) would decrease. Since the reference case projects that EAF will attain a 55-percent share in 2020, no changes are made for the *CEF-JL* advanced case. In the *CEF* study, there was no change in steel industry production flows in the moderate case. The EAF is much less energy intensive than the BOF. However, at this time, the EAF plants are not expected to be able to produce the full range of steel products, which limits their applicability.

Table 26. Reference Case and *CEF* Assumptions for Equipment Retirement Rates
(Percent)

Industry	Reference Case	*CEF* Moderate and Advanced Cases	Comment
Agriculture	1.0	2.5	Included in *CEF-JL*
Mining	1.0	2.5	Included in *CEF-JL*
Construction	1.0	2.5	Included in *CEF-JL*
Food	1.7	2.1	Included in *CEF-JL*
Paper	2.3	2.3	Included in *CEF-JL*
Bulk Chemicals	1.7	2.5	Included in *CEF-JL*
Glass	1.3	1.4	Included in *CEF-JL*
Cement	1.2	2.0	Included in *CEF-JL*
Steel: Blast Furnace/Basic Oxygen Furnace	1.0	1.5	Included in *CEF-JL*
Steel: Electric Arc Furnace	1.5	1.8	Included in *CEF-JL*
Steel: Coke Ovens	1.5	1.8	Included in *CEF-JL*
Steel: Other	2.9	2.9	Included in *CEF-JL*
Aluminum	2.1	2.3	Included in *CEF-JL*
Metal-Based Durables	1.5	1.9	Included in *CEF-JL*
Other Manufacturing	2.3	2.5	Included in *CEF-JL*

Source: Energy Information Administration, Office of Integrated Analysis and Forecasting.

In the industrial model, some industries produce biomass as a byproduct of the production process, notably the pulp and paper industry. The *CEF* analysis assumed more aggressive recovery of biomass byproduct. The reference case assumes that biomass byproduct recovery will increase by 0.2 percent per year. In the advanced technology case, byproduct recovery is assumed to increase by 1.0 percent per year. For the *CEF-JL* moderate case, the reference case assumption is used, while the *CEF-JL* advanced case uses the advanced technology assumption.

CEF Industrial Technology Possibility Curve Modifications

Within the industrial demand model, the rate of change between the current energy intensity and energy intensity in 2020 is defined as the technology possibility curve (TPC) with values interpolated for the intervening years. In most cases, the TPCs are negative in the reference case, indicating that energy intensity is projected to decrease over time.

Almost all the industrial sector policies included in *CEF* were expected to have an impact on the TPCs. However, the effects of the individual policies on the TPCs were not specified. Instead, the overall changes were provided in the *CEF* documentation. In most situations, the changes made in *CEF* were relative to the parameter values used in *AEO99*. For the *CEF-JL* cases, similar changes are incorporated in the current version of NEMS by applying these relative changes to the current parameter values. It is possible that the *CEF* modifications may not be additive to the decline rates in the reference case TPCs, which are generally more rapid than those assumed in *AEO99*, but in the absence of more detailed information it is not possible to determine the extent to which this is the case.

The industrial sector technology changes in *CEF* for the pulp and paper, cement, and steel industries were based on detailed analysis of sector-specific technologies. For the remaining industrial subsectors, the technology changes assumed by the *CEF* authors were based on general trends in energy intensity improvements. In addition, some technology or efficiency improvements that cut across subsectors were implemented by the *CEF* authors.

To represent the combined effect of all the policies in the *CEF* study, the TPCs for the nonintensive industries (agriculture, mining, construction, metal-based durables, and other manufacturing) were multiplied by 1.5 for the moderate case and by 2.0 for the advanced case. For the *CEF-JL* cases, the same modifications are included, with the factors applied to the reference case TPCs. These changes are consistent with the changes implemented in the advanced technology case.

In the *CEF* study, the TPCs for the food and glass industries in the advanced case were set to the values assumed in the *AEO99* high technology case. For the moderate case, the TPCs were set at the midpoint between the *AEO99* reference case and high technology values. For the *CEF-JL* cases, the TPCs for the food and glass industries are modified using the same methodology and the reference and advanced technology case TPCs.

The TPC values for the paper, bulk chemicals, cement, steel, and aluminum industries are taken directly from the *CEF* Appendix A-2. There was no uniform modification of the TPCs for these energy-intensive sectors in the *CEF* analysis. Instead, unit energy consumptions (UECs) were chosen based on external sources to represent specific processes and equipment. The TPCs were then calculated based on the 1994 and 2020 UECs.

Appendix B presents the TPCs used in the *CEF-JL* cases. It should be noted that the exact values of the TPCs generally do not match those published in Appendix A-2 of the *CEF* report because the *CEF*-derived TPCs usually were based on the methodology applied in the *CEF* analysis to the *AEO99* model parameters.

In some instances, the NEMS industrial model could not be modified to incorporate assumptions included in the *CEF* analysis. Most notably, in the pulp and paper industry, integrated black liquor or biomass gasifiers were not included in the moderate or advanced cases. The *CEF* analysis did not address cogeneration within NEMS although there was a discussion of a separate cogeneration analysis. Therefore, for the *CEF-JL* analysis, no cogeneration assumptions are modified in the industrial model.

Impact of *CEF* Policies on Industrial Demand

In the *CEF-JL* moderate case, delivered industrial energy consumption is projected to be 2 percent, or 0.8 quadrillion Btu, lower in 2010 and 4 percent, or 1.6 quadrillion Btu, lower in 2020 than in the reference case (Table 27). Projected consumption of all energy sources is lower in the moderate case, with petroleum products declining the most in 2010 and in 2020.The *CEF-JL* moderate case results in a larger decrease in projected energy consumption than the advanced technology case, even though the advanced technology TPCs generally decline more rapidly. The larger projected energy savings in the *CEF-JL* moderate case are due to the boiler and building efficiency improvements which are not assumed in the advanced technology case. CO_2 emissions in the industrial sector are projected to be reduced by 11 and 19 million metric tons carbon equivalent, or 2 and 3 percent, in 2010 and 2020, compared to reference case levels.

The *CEF-JL* advanced case assumes higher availability of renewables in the paper industry. Total renewable energy consumption in the industrial sector is projected to be higher by 5 percent, or 0.1 quadrillion Btu, in 2010 and by 12 percent, or 0.4 quadrillion Btu, in 2020 as compared with the reference case. Consumption of all other energy sources is projected to be lower in both 2010 and 2020 in the *CEF-JL* advanced case. Partly due to the $50 carbon fee, projected delivered industrial energy consumption is reduced by 5 and 8 percent in 2010 and 2020, respectively, relative to the reference case, and projected CO_2 emissions are reduced by 60 and 96 million metric tons carbon equivalent, or 11 and 16 percent.

Table 27. Industrial Sector Projections in the *CEF-JL* Moderate and Advanced Cases, 2010 and 2020

Projections	1999	Reference	*CEF-JL* Moderate: Without Emissions Limits	*CEF-JL* Moderate: With Emissions Limits	*CEF-JL* Advanced: Without Emissions Limits	*CEF-JL* Advanced: With Emissions Limits
		2010				
Industrial Output (Billion 1992 Dollars)	**4,722**	**6,223**	**6,215**	**6,214**	**6,205**	**6,203**
Industrial Output Growth (Annual Percent, 1999-2010)	**—**	**2.54**	**2.53**	**2.53**	**2.51**	**2.51**
Delivered Energy Consumption (Quadrillion Btu)	**27.6**	**31.1**	**30.4**	**30.4**	**29.7**	**29.6**
Petroleum	9.5	10.5	10.2	10.2	9.9	10.0
Natural Gas	9.8	11.3	11.0	11.2	10.7	10.7
Coal	2.5	2.6	2.5	2.5	2.4	2.3
Renewables	2.2	2.6	2.6	2.6	2.8	2.8
Purchased Electricity	3.6	4.2	4.1	3.9	3.9	3.9
Delivered Energy Intensity (Thousand Btu per 1992 Dollar of Output)	**5.84**	**5.00**	**4.89**	**4.89**	**4.78**	**4.78**
Change in Delivered Energy Intensity (Annual Percent, 1999-2010)	**—**	**-1.39**	**-1.60**	**-1.59**	**-1.79**	**-1.80**
Average Delivered Prices (1999 Dollars per Million Btu)	**5.29**	**5.62**	**5.33**	**5.99**	**5.44**	**5.79**
Electricity	13.12	12.04	11.15	15.09	13.18	14.01
Natural Gas	2.79	3.46	3.12	3.56	2.96	3.42
Petroleum	5.54	6.07	6.01	5.92	5.60	5.75
Effective Delivered Prices[a] (1999 Dollars per Million Btu)	**5.29**	**5.62**	**5.33**	**5.99**	**6.03**	**6.39**
Electricity	13.12	12.04	11.15	15.09	13.18	14.01
Natural Gas	2.79	3.46	3.12	3.56	3.67	4.12
Petroleum	5.54	6.07	6.01	5.92	6.19	6.34
CO_2 Emissions (Million Metric Tons Carbon Equivalent)	**480**	**533**	**522**	**468**	**473**	**454**
		2020				
Industrial Output (Billion 1992 Dollars)	**4,722**	**8,083**	**8,062**	**8,060**	**8,042**	**8,043**
Industrial Output Growth (Annual Percent, 1999-2020)	**—**	**2.59**	**2.58**	**2.58**	**2.57**	**2.57**
Delivered Energy Consumption (Quadrillion Btu)	**27.6**	**34.7**	**33.2**	**33.2**	**32.0**	**32.0**
Petroleum	9.5	11.6	10.9	11.0	10.5	10.5
Natural Gas	9.8	12.7	12.2	12.7	11.6	11.6
Coal	2.5	2.6	2.5	2.5	2.3	2.3
Renewables	2.2	3.1	3.0	3.0	3.4	3.4
Purchased Electricity	3.6	4.8	4.5	4.0	4.2	4.2
Delivered Energy Intensity (Thousand Btu per 1992 Dollar of Output)	**5.84**	**4.30**	**4.11**	**4.12**	**3.98**	**3.98**
Change in Delivered Energy Intensity (Annual Percent, 1999-2020)	**—**	**-1.45**	**-1.65**	**-1.64**	**-1.81**	**-1.81**
Average Delivered Prices (1999 Dollars per Million Btu)	**5.29**	**5.82**	**5.47**	**5.96**	**5.58**	**5.73**
Electricity	13.12	12.07	11.77	15.57	13.63	13.71
Natural Gas	2.79	3.73	3.11	3.46	2.99	3.26
Petroleum	5.54	6.12	6.01	5.90	5.64	5.71
Effective Delivered Prices[a] (1999 Dollars per Million Btu)	**5.29**	**5.82**	**5.47**	**5.96**	**6.16**	**6.31**
Electricity	13.12	12.07	11.77	15.57	13.63	13.71
Natural Gas	2.79	3.73	3.11	3.46	3.70	3.97
Petroleum	5.54	6.12	6.01	5.90	6.22	6.28
CO_2 Emissions (Million Metric Tons Carbon Equivalent)	**480**	**585**	**566**	**494**	**489**	**472**

[a]Effective delivered price reflects the cost impact of CO_2 emission allowances in cases that include a CO_2 limit.

Source: National Energy Modeling System, runs SCENABS.D080301A, SCENCBS.D080301A, SCENCEM.D081601A, SCENDBS.D092601B, and SCENDEMR.D092701A.

Impact of Emissions Limits on Industrial Demand in the *CEF-JL* Cases

The emissions limits on the electricity generation sector have a similar effect on industrial sector energy demand in the *CEF-JL* cases as in the advanced technology case. In both the *CEF-JL* moderate and advanced cases with emissions limits, total projected delivered energy consumption is essentially unchanged from the same cases without the limits.

Applying the emissions limits in the *CEF-JL* moderate case is projected to raise the industrial electricity price by 35 and 32 percent in 2010 and 2020, respectively, while effective natural gas prices are projected to increase by 14 and 11 percent. As a result, purchased electricity is projected to be reduced by 5 percent in 2010 and by 11 percent in 2020. Compared to the case without emissions limits, projected natural gas consumption in the *CEF-JL* moderate case with limits is higher by 2 percent in 2010 and 4 percent in 2020, accounting for the slight increase in total consumption. Cogeneration using natural gas is projected to be 50 percent higher in 2010 than in the case without emissions limits and 102 percent higher in 2020.

In the *CEF-JL* advanced case, which includes a carbon fee of $50 per metric ton carbon equivalent, the difference in projected delivered industrial energy consumption between the two cases with and without emissions limits is negligible. In 2010, projected electricity and effective natural gas prices both increase in the case with emissions limits, 6 percent and 12 percent, respectively, compared to the case without the limits. In 2020, effective natural gas prices are projected to be higher by 7 percent and electricity prices are slightly higher. Overall, the imposition of the emissions limits is projected to cause very little change in fuel mix in the *CEF-JL* advanced case.

In the *CEF-JL* moderate case with emissions limits, CO_2 emissions in the industrial sector are projected to be lower by 54 and 72 million metric tons carbon equivalent (10 and 13 percent) in 2010 and 2020, respectively, compared to the case without limits. In the *CEF-JL* advanced case, projected CO_2 emissions are reduced by 19 million and 17 million metric tons carbon equivalent (4 and 3 percent) in 2010 and 2020, respectively. In all instances, the reductions are largely due to the use of electricity in the industrial sector, either through lower projected electricity demand or a change in the composition of the fuels used to generate electricity.

Transportation

Transportation sector technology and policy assumptions in the *CEF* study reflected reductions in component costs as well as efficiency improvements necessary for the economic viability and market adoption and penetration of advanced vehicle technologies. The assumptions in the *CEF* analysis reflected a very high level of optimism. The authors of *CEF* assumed dramatic increases in funding for vehicle-related research and development and a high level of optimism that this research and development will prove successful in meeting all advanced technology efficiency and cost goals. The same increased funding also led to the successful early market introduction of low-cost high efficiency technologies, a similarly optimistic outcome.

Efficiency improvements achieved market success through the adoption and implementation of a mixture of low-cost advanced technologies, new policies, and assumed changes in manufacturer and consumer market behavior. The *CEF* authors assumed that a shift in the light vehicle market would occur, increasing the demand for high efficiency vehicles. This shift in demand was implemented through an increase in payback period from four to twelve years, while discount rates were increased from 8 to 15 percent. Other policies complemented research and development by stimulating demand for new technologies and promoting efficient system operation.

For the transportation sector, the input assumptions and modifications to model algorithms in the *CEF* analysis are replicated in the *CEF-JL* cases where applicable. In some instances, the model structure in the *AEO2001* version of the model has been modified to the extent that the changes indicated in the *CEF* report are no longer applicable, as discussed below. In addition, more current information is available for technology cost and potential efficiency improvements and, as a result, there are a few instances where assumptions regarding advanced technologies in the reference case are more optimistic than those in the *CEF* analysis.

Light-Duty Vehicles

Improvements in the efficiency of light-duty vehicles occurred as the result of technology cost reductions achieved by increased government and industry research and development spending, combined with tax credits. In *CEF*, the authors assumed that government and industry research and development spending would be increased 50 percent over 1999 levels in the moderate case and 100 percent in the advanced case. In both cases, spending increases were ramped up within a five-year period. No assumptions associated with advanced technologies were changed prior to year 2003 because it was assumed that funding increases would not see appreciable results before this time. It is important to note that, although the assumptions made in the *CEF* analysis are implemented in this study, the required increases in research and development spending have not occurred. As a result, the implementation of these assumptions reflects a level of optimism that exceeds the underlying assumptions.

Tax Credit for High-Efficiency Vehicles

CEF included a tax credit that reduced the cost of hybrid electric and fuel cell vehicles by $1,000 to $5,000 depending on the level of efficiency improvement, and the cost reduction was phased out after vehicle production reached 50,000 units per year. Hybrid electric vehicles maintained a continuous $1,000 reduction throughout the projection period. This policy was designed to stimulate the demand for electric drivetrain light vehicles by providing a tax credit. Currently, there are similar State-administered policies of this type in effect. Although these policies have not shown significant success to date, they are expected to have greater impact on the market as product offerings increase. It also important to note that tax credits for the most efficient fuel cell vehicles alone would reach $250 million per year before being phased out. This policy is implemented in the *CEF-JL* cases using the same assumptions as the *CEF* analysis.

Invigorated Government Fleet Programs

The *CEF* analysis contended that, if Federal and State fleet vehicle requirements under the Energy Policy Act of 1992 were met, then alternative fuel availability would increase as a result. This, in turn, would provide greater consumer acceptance of alternative-fuel vehicles, thus increasing their market penetration. Fuels specifically impacted by this assumption included ethanol and hydrogen with availability increasing to at least 50 percent by 2020. As stated in the *CEF* report, the *AEO99* projections estimated that some regions of the country would have ethanol fuel availability exceeding 50 percent in 2020. For the *CEF-JL* cases, fuel availability for ethanol and hydrogen reaches a minimum of 50 percent in each Census region, as assumed in the *CEF* study.

Increases in Research and Development Spending

This policy, which was described above, resulted in earlier market introduction dates as well as decreased incremental costs and improved efficiency of advanced technologies and reflected a high level of optimism as discussed above. Conventional and advanced vehicle technologies were impacted in the following ways:

- The introduction dates for conventional technologies were accelerated by 30 percent in the moderate case and 40 percent in the advanced case.
- Two new lightweight materials technologies were added.
- The efficiency of hybrid electric and fuel cell technologies were incrementally increased and the cost incrementally decreased.

For this analysis, the introduction dates, efficiency improvements, and the availability of new conventional technologies reflect the *CEF* assumptions. With respect to *CEF* assumptions regarding hybrid electric and fuel cell vehicles, the vehicle choice algorithms have been updated in the *AEO2001* version of NEMS to reflect a more logical costing structure for these technologies. As a result, some of the fuel cell assumptions in the *CEF* study are not implemented. These include replacing the incremental cost equations with a single equation representing fuel cell costs and implementing an exponential fuel cell cost equation that incorporates a rate of decline that is itself declining exponentially. Assumptions regarding fuel cell cost representing kilowatts required per ton of vehicle weight, stack cost, motor cost, and reformer cost are modified to reflect the *CEF* values.

Cellulosic Ethanol Commercialization

The *AEO99* reference case and the *CEF* business-as-usual case assumed that the production cost of biomass (cellulosic) ethanol would decline 20 percent by 2020 and that 250 million gallons of annual capacity would be added annually. The *CEF* moderate and advanced cases assumed that loan guarantees, tax incentives, or subsidies would reduce or eliminate the added risk of investment in new biomass ethanol capacity. The production cost was assumed to decline 50 percent by 2020, and the annual rate of capacity expansion was assumed to be 650 million gallons starting in 2006.

The reduction in production costs for biomass ethanol was similar to those in a recent EIA study, which assumed a 33-percent reduction by 2015 in the reference case and a 66-percent reduction in a high technology case.[42] However, the rates of capacity expansion assumed in the *CEF* moderate and advanced cases were quite high. The biomass ethanol industry was projected to have 9.8 billion annual gallons of capacity by 2020, but output of 7.0 billion gallons and 7.3 billion gallons in the moderate and advanced cases, respectively. This implied capacity utilization of 74 percent in the advanced case, which is very low for the refining industry, where capacity utilization rates generally average more than 90 percent.

Vehicle Choice Model Modifications

The vehicle choice model used for the *CEF* analysis incorporated extensive changes to the *AEO99* version of NEMS. One significant change to the methodology greatly increased the penetration of alternative-fuel and

[42]Energy Information Administration, *Outlook for Biomass Ethanol and Production and Demand* (Washington, DC, April 2000), web site www.eia.doe.gov/oiaf/analysispaper/biomass.html.

advanced technology vehicles. However, this methodology is no longer used in the *AEO2001* version of NEMS for market penetration estimation.

In addition, vehicle choice model coefficients were modified in *CEF*-NEMS to provide greater price elasticity than represented in the *AEO99* version of NEMS. Since the *CEF* study was completed, the NEMS vehicle choice model has been modified to incorporate a new nesting structure and new vehicle attribute coefficients that also provide greater price elasticity. As a result, the changes reflected in the *CEF* analysis do not apply.

Vehicle Miles Traveled Reduction Programs

In the *CEF* report, it was stated that the annual growth rate of 1.6 percent in vehicle miles traveled projected in the *AEO99* reference case from 1997 to 2020 was very low and that these growth rates would be unlikely without the successful implementation of travel reduction programs. The *CEF* authors noted that historical trends reveal an average annual growth rate in vehicle miles traveled of 2.8 percent between 1974 and 1995, further noting that other experts have projected that travel by light-duty vehicles will grow at approximately 2.0 percent per year over the next two decades.

The reference case projects an average annual growth in vehicle miles traveled of 1.9 percent through 2020, which incorporates current policies designed to reduce travel in the future. Although this is closer to the values cited in the *CEF* study as a likely projection, the effective implementation of travel reduction policies is a very difficult task requiring coordinated efforts between State and local governments. As stated in the *CEF* report, this encompasses a great effort with a commitment to changing the travel characteristics of commuters, making this a very difficult set of programs to analyze. As a result, this analysis assumes that the growth rates in vehicle miles traveled projected in the reference case adequately reflect the policies enacted for the *CEF* study.

Intelligent Traffic Control Systems

This program implemented advanced electronic control systems designed to reduce travel times for commuters. In effect, the impact of traffic congestion was reduced, reducing the fuel economy degradation factor by 1 percent over the forecast period. The fuel economy degradation factor represents a decrease in on-road fuel economy from the values reported by the Environmental Protection Agency. Traffic congestion is one of several contributing factors in fuel economy degradation, and as travelers reduce the amount of time in congested driving conditions, on-road fuel economy is increased. This assumption is directly implemented in the *CEF-JL* cases.

Voluntary Agreements

This policy, implemented in the *CEF* advanced case only, assumed that voluntary agreements would be adopted to promote greater vehicle manufacturer attention to fuel economy relative to other vehicle attributes. This policy was implemented by reducing consumer demand for horsepower. For the *CEF-JL* advanced case, modifications for horsepower demand reflect those implemented in the *CEF* study. However, in some cases, the coefficients for horsepower demand used in the reference case are already lower than those used in the *CEF* study, so the associated impacts on fuel economy are not as large.

"Variabilization" Policies

This policy, again implemented in the advanced case only, simulated a pay-at-the-pump insurance surcharge to all motor vehicles. This surcharge reduced the fixed cost of automobile insurance by "variabilizing" a portion of insurance costs to the amount of miles driven per year. In effect, this allowed consumers to lower insurance costs by either driving less or by driving a more efficient vehicle. The *CEF* fuel price increases were implemented to reflect an increase of $0.34 per gallon from 2003 to 2012 and $0.51 per gallon from 2013 to 2020 for all highway fuels. These same assumptions are in the *CEF-JL* advanced case. Although it makes sense that automobile insurance should vary by the amount of vehicle travel, the probability that such a program would be implemented on a national level is very unlikely. Issues surrounding accident risk by region and disbursement of funds to insurance companies would require significant study and development and could take many years implement.

Freight Trucks

In the *CEF* analysis, improvements in heavy truck efficiency were accomplished primarily through increased research and development spending by government and industry. This resulted in the adoption of new technologies not included in the *AEO99* reference case as well as efficiency improvements of selected technologies included in the reference case. Similar to the light-duty vehicle technology assumptions, the *CEF* authors assumed a 50-percent increase in research and development funding in the moderate case and a 100-percent increase in the advanced case.

The technology assumptions for the *CEF* moderate case reflected the adoption of the LE-55 engine, a 55-percent efficient diesel engine, and included improvements to the current advanced technologies. The LE-55 engine was introduced in 2010. This technology was not included in the *AEO99* reference case but is included in the current reference case where it is assumed to begin market penetration in 2009. In the *CEF-JL* moderate case, the maximum market share is set to 100 percent for both medium and heavy trucks and efficiency improvements are adjusted to reflect *CEF* values. Turbo-compounding is deleted and replaced by materials substitution, which reflects an improvement in efficiency realized from a reduction in vehicle empty weight travel. This policy is introduced in 2005. In addition, incremental efficiency improvements for advanced tires and lubricants are increased from 5 percent to 10 percent. The incremental efficiency improvements for electronic transmission controls are set to 5 percent for medium trucks and 3 percent for heavy trucks and for advanced drag reduction are set to 7 percent for medium trucks and 18 percent for heavy trucks. Initial penetration of advanced technologies in the freight truck model is represented using a trigger point methodology. For this study, all technology trigger prices are set below the lowest projected fuel price as in the *CEF* analysis. This assumes that all technologies become cost effective, indicating that research and development successes are critical in achieving marketable advanced technologies.

The *CEF* advanced case included all assumptions made in the moderate case, added hybrid technology in 2005, and advanced the introduction date of the LE-55 technology. The hybrid technology was not included in the *AEO99* reference case but is included for medium trucks in the current reference case. For the *CEF-JL* advanced case, hybrid technology is included for heavy trucks as well, assuming a maximum market penetration of 25 percent for diesel heavy trucks and 100 percent for all other gasoline trucks. The fuel efficiency benefit is 25 percent for diesel trucks and 45 percent for gasoline trucks. The LE-55 technology introduction date is advanced to 2005 and medium truck efficiency improvement is increased. As stated above, the ability to meet these technology goals hinges on the assumption that significant investment is made in research and development and that the investment is successful. Without these significant increases in funding, there is little chance that these technologies will meet the stated cost and efficiency goals.

Air

CEF policies and increased research and development spending were assumed to achieve a 5-percent reduction in air traffic fuel use and were incorporated by increasing the rate of efficiency improvement, from 0.18 percent to 0.34 percent for wide-body aircraft and from 0.44 percent to 0.60 percent for narrow-body aircraft. This improvement reflected a combination of technology adoption and increased load factors. The *CEF* study added one new technology, blended wing body aircraft, and assumed the values in NEMS for efficiency improvements and costs for existing technologies.

No detail was provided in *CEF* on the efficiency or cost of the blended wing body technology. The *CEF* study indicated that load factors were increased from 72 percent to 73 percent for international travel and made no explicit statement regarding domestic load factors other than to state that current domestic load factors were higher than the values projected in *AEO99*.

Efficiency improvements in the *CEF* moderate and advanced cases were intended to reflect "general improvement in aircraft operating efficiency due to more effective flight planning and reductions in excessive time spent waiting in the air or waiting on the ground due to traffic congestion." Although it is true that reducing aircraft taxi time will reduce fuel use, much of the traffic congestion expected to occur in the future will be due to limited infrastructure. More effective flight planning would certainly increase efficiency, but without airport expansion there will be limits to the amount of efficiency realized. NEMS does not address airport operation efficiency and therefore such improvements are reflected via improved aircraft efficiency and / or increased load factors. The *CEF* study assumed aggressive growth in aircraft efficiency, which was implemented through adjustments in the trigger price, and moderate increases in load factors. The *CEF-JL* cases reflect the values achieved in *CEF*.

Rail

The *CEF* study assumed that fuel cell propulsion, advanced electric motors, advanced diesel engines, rail lubrication systems, and information control systems would be implemented to improve rail efficiency. In the moderate case, rail efficiency increased to 3.5 ton-miles per thousand Btu by 2020, 13 percent higher than in the reference case. In addition, it was assumed that 2 percent of freight truck ton-miles would be shifted to rail. The report indicated that this increased rail travel 33 billion ton-miles by 2020, but no reduction in truck vehicle miles traveled was provided. In the advanced *CEF* case, rail efficiency increased to 3.9 ton-miles per thousand Btu by 2020, 26 percent higher than in the reference case. It was assumed that 5 percent of freight truck ton-miles would be shifted to rail, increasing rail travel 83 billion ton-miles by 2020. For the *CEF-JL* cases, the efficiency improvements are implemented but not the shift in travel from truck to rail. Although rail travel is measured in ton-miles traveled, truck freight travel is measured in vehicle miles traveled. No explanation was offered in *CEF* regarding the conversion of truck vehicle miles traveled to rail ton-miles traveled, making it impossible to determine the overall effect on freight travel from a shift to rail travel.

Marine

The *CEF* study assumed that marine vessel efficiency would improve to 2.86 ton-miles per thousand Btu in the moderate case and 2.95 ton-miles per thousand Btu in the advanced case by 2020, 6 percent and 9 percent higher, respectively, than in the reference case. This assumed the adoption of fuel cell technology and the implementation of improved maintenance and operations programs. The reference case assumes that marine vessel efficiency increases to 2.99 ton-miles per thousand Btu by 2020, as updated to reflect more recent historical trends, so no additional changes are made in the *CEF-JL* cases.

Impact of *CEF* Policies on Transportation Demand

For the transportation sector, the *CEF* study assumed significant increases in research and development along with fundamental shifts in the demand for efficiency across all modes. The assumptions for incremental technology cost and efficiency improvement reflected a greater level of optimism and success for advanced technologies than in the reference case. The *CEF* assumptions or modifications are incorporated in the *CEF-JL* cases to the extent feasible, although there are instances where they no longer apply to the current model as noted above.

In the *CEF-JL* moderate case, new light-duty vehicle fuel efficiency is projected to increase to 28.0 miles per gallon in 2010 and 29.0 miles per gallon in 2020, representing a 3-percent increase over the reference case in both years (Table 28) Heavy truck efficiency is projected to increase to 6.8 miles per gallon in 2010 and 7.4 miles per gallon in 2020, increases of 6 and 7 percent over the reference case in those two years, respectively. In 2010, the other modes are expected to show little change between the reference case efficiency values and those projected in the *CEF-JL* moderate case. In 2020, projected air efficiency increases 4 percent above the reference case and rail and marine efficiencies show little change. Total transportation energy use is expected to be lower by 2 percent, or 0.7 quadrillion Btu, in 2010 and 5 percent, or 1.8 quadrillion Btu, in 2020 (Table 29). Projected transportation CO_2 emissions are lower by 14 and 46 million metric tons carbon equivalent, or 2 and 6 percent, in 2010 and 2020, respectively.

In the *CEF-JL* advanced case which includes a $50 carbon fee, new light-duty vehicle fuel efficiency is projected to increase to 31.6 miles per gallon in 2010 and 34.4 miles per gallon in 2020. These efficiencies represent increases of 16 percent in 2010 and 22 percent in 2020 relative to the reference case. The projected efficiency of heavy trucks shows no significant increase over the moderate case in 2010 but increases to 7.6 miles per gallon in 2020, an improvement of 10 percent over the reference case. For 2010, the air and rail modes are expected to have efficiency improvements of 2 and 6 percent, respectively, over the reference case, with the efficiencies in 2020 improving to 8 and 15 percent over the reference case for the two modes, respectively.

Significant travel reductions are projected for light-duty vehicle and rail travel in the *CEF-JL* advanced case. Highway fuel costs are expected to increase for light-duty vehicles, as a result of pay-at-the-pump insurance and the carbon fee, reducing the projected demand for light-duty vehicle travel by 8 percent in 2010 and 7 percent in 2020. The reduction in projected rail travel comes primarily from reduced coal shipments, lowering rail travel by 10 and 14 percent in 2010 and 2020, relative to the reference case. In 2010, total projected delivered transportation energy use is reduced by 11 percent, or 3.6 quadrillion Btu, and by 18 percent, or 6.7 quadrillion Btu, in 2020. Projected transportation CO_2 emissions are reduced by 69 and 137 million metric tons carbon equivalent, or 11 and 19 percent, in 2010 and 2020, respectively.

In 2020, there is a slight increase in the projected use of ethanol in the *CEF-JL* moderate case. Cellulose ethanol production is projected to reach 516 thousand barrels per day by 2020, higher than the 456 thousand barrels per day in the *CEF* study, mainly due to the lack of any State limits on methyl tertiary butyl ether (MTBE) in *CEF*.[43] The ban in California alone is expected to add 40 thousand barrels per day to ethanol consumption. In the *CEF-JL* advanced case, cellulose ethanol production is projected to reach 412 thousand barrels per day in 2020. E85 consumption is similar in both cases; however, in the *CEF-JL* moderate case, 513 thousand barrels per day of ethanol is projected to be blended into gasoline in 2020, and in the *CEF-JL* advanced case only 372 thousand barrels per day of ethanol is projected to be blended into gasoline. Projected ethanol demand is lower in the *CEF-JL* advanced case than in the *CEF-JL* moderate case due to lower gasoline demand. In 2020, the projected price of ethanol in the reference case is $48.13 per barrel, declining to $32.55 per barrel in the *CEF-JL* moderate case, largely due to the ethanol commercialization program, and to $29.80 per barrel in the *CEF-JL* advanced case, as a result of the lower demand.

Impact of Emissions Limits on Transportation Demand in the *CEF-JL* Cases

In both the moderate and advanced *CEF-JL* cases, the emissions limits on electricity generators have no

[43]MTBE is a widely used gasoline blending component, initially added as an octane enhancer and now used to meet oxygen requirements in reformulated gasoline. There are now concerns about MTBE contamination of water supplies.

significant impact on efficiency improvements. The only significant impact on travel is a reduction in rail travel due to lower shipments of coal. Fuel consumption by rail is slightly lower and by pipelines is slightly higher than in the cases without the emissions limits. As a result, no significant change is projected for total transportation energy consumption or CO_2 emissions as a result of the emissions limits.

Electricity and Renewables

The *CEF* study analyzed policies that would bring about a reduction in CO_2 emissions from electricity generators through three mechanisms: increasing the efficiency of individual fossil-fired power plants, reducing or sequestering the emissions from these plants, and fuel switching, including increased use of renewable sources of generation. The policies focused on enhanced research and development that was assumed to bring about additional technology advances and reduced costs, along with tax credits to encourage the use of renewable generation. The analysis also assumed full competition in the electricity generation sector. The following sections discuss the *CEF* policies and how they were incorporated in the *CEF-JL* cases.

Enhanced Research and Development: Fossil

In the *CEF* study, increases in research and development were assumed to result in improvements in the performance of new technologies and lower capital costs. For the moderate case in *CEF*, the technology characteristics were the same as the assumptions from the *AEO99* high fossil case, which assumed approximately a 15-percent

Table 28. Transportation Efficiency and Travel in the *CEF-JL* Moderate and Advanced Cases, 2010 and 2020

			CEF-JL Moderate		*CEF-JL* Advanced	
Projections	1999	Reference	Without Emissions Limits	With Emissions Limits	Without Emissions Limits	With Emissions Limits
			2010			
Energy Efficiency Indicators						
New Light-Duty Vehicle (Miles per Gallon)	24.2	27.2	28.0	28.1	31.6	31.6
New Car (Miles per Gallon)	27.9	32.5	34.5	34.5	38.0	38.0
New Light Truck (Miles per Gallon)	20.8	23.3	23.5	23.5	26.9	26.9
Light-Duty Fleet (Miles per Gallon)	20.5	21.0	21.2	21.3	22.8	22.8
Aircraft Efficiency (Seat Miles per Gallon)	51.7	56.1	56.2	56.2	57.5	57.5
Freight Truck Efficiency (Miles per Gallon)	6.0	6.4	6.8	6.8	6.8	6.8
Rail Efficiency (Ton Miles per Thousand Btu)	2.8	3.1	3.1	3.1	3.3	3.3
Domestic Shipping (Ton Miles per Thousand Btu)	2.3	2.7	2.7	2.7	2.7	2.7
Travel						
Light-Duty Vehicle (Billion Miles)	2,394	3,059	3,061	3,060	2,816	2,816
Heavy-Duty Vehicle (Billion Miles)	204	279	275	275	275	275
Air (Billion Seat Miles)	1,099	1,586	1,594	1,594	1,588	1,586
Rail (Billion Ton Miles)	1,353	1,708	1,680	1,453	1,545	1,462
Domestic Shipping (Billion Ton Miles)	661	778	754	748	739	738
			2020			
Energy Efficiency Indicators						
New Light-Duty Vehicle (Miles per Gallon)	24.2	28.1	29.0	29.0	34.4	34.4
New Car (Miles per Gallon)	27.9	32.5	34.5	34.5	40.1	40.1
New Light Truck (Miles per Gallon)	20.8	24.7	25.0	25.0	30.0	30.0
Light-Duty Fleet (Miles per Gallon)	20.5	21.5	22.1	22.1	25.8	25.8
Aircraft Efficiency (Seat Miles per Gallon)	51.7	60.3	62.5	62.3	65.4	65.4
Freight Truck Efficiency (Miles per Gallon)	6.0	6.9	7.4	7.4	7.6	7.6
Rail Efficiency (Ton Miles per Thousand Btu)	2.8	3.4	3.5	3.5	3.9	3.9
Domestic Shipping (Ton Miles per Thousand Btu)	2.3	3.0	3.0	3.0	3.0	3.0
Travel						
Light-Duty Vehicle (Billion Miles)	2,394	3,575	3,579	3,579	3,315	3,316
Heavy-Duty Vehicle (Billion Miles)	204	352	339	338	337	337
Air (Billion Seat Miles)	1,099	2,316	2,340	2,340	2,332	2,332
Rail (Billion Ton Miles)	1,353	1,967	1,881	1,609	1,693	1,594
Domestic Shipping (Billion Ton Miles)	661	890	826	812	795	796

Source: National Energy Modeling System, runs SCENABS.D080301A, SCENCBS.D080301A, SCENCEM.D081601A, SCENDBS.D092601B, and SCENDEMR.D092701A.

Table 29. Transportation Energy Consumption in the *CEF-JL* Moderate and Advanced Cases, 2010 and 2020

Projections	1999	Reference	*CEF-JL* Moderate: Without Emissions Limits	*CEF-JL* Moderate: With Emissions Limits	*CEF-JL* Advanced: Without Emissions Limits	*CEF-JL* Advanced: With Emissions Limits
		2010				
Energy Use by Mode (Quadrillion Btu)						
Light-Duty Vehicle	15.5	19.2	18.9	18.9	16.2	16.2
Heavy-Duty Vehicle	4.6	5.8	5.4	5.4	5.4	5.4
Air	3.5	4.6	4.6	4.6	4.5	4.5
Rail	0.6	0.7	0.6	0.6	0.6	0.5
Marine	1.3	1.5	1.5	1.5	1.4	1.4
Pipeline Fuel	0.7	0.9	0.9	1.0	0.9	0.9
Lubricants	0.2	0.3	0.3	0.3	0.3	0.3
Total	**26.3**	**32.8**	**32.0**	**32.1**	**29.2**	**29.2**
Energy Use by Fuel Type (Quadrillion Btu)						
Motor Gasoline	15.9	18.9	18.5	18.5	16.1	16.1
Distillate	5.1	7.0	6.7	6.6	6.4	6.4
Jet Fuel	3.5	4.5	4.5	4.5	4.4	4.4
Residual Fuel	0.7	0.9	0.9	0.9	0.9	0.9
Other Petroleum	0.3	0.4	0.4	0.4	0.4	0.4
Petroleum Subtotal	*25.5*	*31.6*	*31.0*	*30.9*	*28.1*	*28.1*
Methanol (M85)	0.00	0.00	0.01	0.01	0.00	0.00
Ethanol (E85)	0.01	0.03	0.03	0.03	0.03	0.03
Electricity	0.06	0.12	0.10	0.10	0.10	0.10
Compressed Natural Gas	0.02	0.09	0.09	0.09	0.08	0.08
Liquid Hydrogen	0.00	0.00	0.01	0.01	0.01	0.01
Pipeline Fuel	0.7	0.9	0.9	1.0	0.9	0.9
Total	**26.3**	**32.8**	**32.0**	**32.1**	**29.2**	**29.2**
CO_2 Emissions (Million Metric Tons Carbon Equivalent)	**498**	**626**	**612**	**610**	**557**	**557**
		2020				
Energy Use by Mode (Quadrillion Btu)						
Light-Duty Vehicle	15.5	21.8	21.0	21.0	16.7	16.7
Heavy-Duty Vehicle	4.6	6.7	6.1	6.1	5.9	5.9
Air	3.5	6.0	5.9	5.9	5.7	5.7
Rail	0.6	0.7	0.7	0.6	0.6	0.5
Marine	1.3	1.5	1.5	1.5	1.5	1.5
Pipeline Fuel	0.7	1.1	1.0	1.0	0.9	1.0
Lubricants	0.2	0.3	0.3	0.3	0.3	0.3
Total	**26.3**	**38.2**	**36.3**	**36.3**	**31.5**	**31.5**
Energy Use by Fuel Type (Quadrillion Btu)						
Motor Gasoline	15.9	21.3	20.3	20.3	16.2	16.2
Distillate	5.1	8.2	7.6	7.5	7.1	7.0
Jet Fuel	3.5	6.0	5.9	5.9	5.7	5.7
Residual Fuel	0.7	0.9	0.9	0.9	0.9	0.9
Other Petroleum	0.3	0.4	0.4	0.4	0.4	0.4
Petroleum Subtotal	*25.5*	*36.7*	*35.0*	*34.9*	*30.2*	*30.2*
Methanol (M85)	0.00	0.00	0.01	0.01	0.01	0.01
Ethanol (E85)	0.01	0.04	0.06	0.06	0.05	0.05
Electricity	0.06	0.17	0.14	0.14	0.14	0.14
Compressed Natural Gas	0.02	0.16	0.15	0.15	0.13	0.13
Liquid Hydrogen	0.00	0.00	0.02	0.02	0.02	0.02
Pipeline Fuel	0.7	1.1	1.0	1.0	0.9	1.0
Total	**26.3**	**38.2**	**36.3**	**36.3**	**31.5**	**31.5**
CO_2 Emissions (Million Metric Tons Carbon Equivalent)	**498**	**730**	**684**	**682**	**593**	**593**

Source: National Energy Modeling System, runs SCENABS.D080301A, SCENCBS.D080301A, SCENCEM.D081601A, SCENDBS.D092601B, and SCENDEMR.D092701A.

decrease in the initial overnight cost of the advanced fossil technologies and slight improvements in operating efficiency, or heat rates. For the advanced case in *CEF*, further improvements in heat rates were assumed, based on the Vision 21 program goals put forth by the DOE Office of Fossil Energy.

Since *AEO99*, the overnight costs have been updated for all technologies, and significant changes have been made to the representation of technology learning.[44] For the *CEF-JL* moderate and advanced cases, the assumptions for the overnight costs from the *AEO2001* high fossil case are used. In this case, capital costs are the same as in the reference case for all fossil technologies except integrated coal-gasification combined cycle, which has the same initial cost, but assumes costs will decline due to learning effects, resulting in a reduction in the overnight cost of 25 percent by 2020. Because the capital costs for new natural gas technologies that are achieved through the learning effects in NEMS are considered optimistic, no further reduction is made in the *AEO2001* high fossil case. These costs are somewhat higher than assumed in *AEO99* and in *CEF*. The *CEF-JL* advanced case assumes the same overnight costs as the *CEF-JL* moderate case.

The *CEF-JL* cases use the same input assumptions for fossil heat rates that were used in the *CEF* analysis. For the moderate case, this reflects a slight improvement of about 2 percent by 2010. In the advanced case, fairly significant improvements, in the range of 15 to 25 percent, are achieved by 2015. These assumptions in the advanced case are consistent with DOE's Office of Fossil Energy Vision 21 program goals and with the *AEO2001* high fossil case.[45] Achieving these program goals will require aggressive research and development of the technologies.

Enhanced Research and Development: Nuclear

The advanced nuclear technology cost assumption was changed in the *CEF* analysis. In the moderate case, the technological optimism multiplier, meant to adjust for the tendency to underestimate the cost increases for the first few plants of a new design, was removed, justified by the *CEF* authors by expected experience gained through international construction. This multiplier was 19 percent in *AEO99* and 15 percent in *AEO2001*. Since there have been no orders or construction of the specific advanced design being modeled (Westinghouse's AP600) anywhere in the world, this cost multiplier is not removed in the *CEF-JL* cases, achieving the same result in the *CEF* moderate case of no construction of new nuclear plants. In the *CEF* advanced case, the initial capital cost was reduced by 10 percent to reflect increased research and development, and this change is also in the *CEF-JL* advanced case.

Production Tax Credits for Renewables

There currently exists a production tax credit for new wind and closed-loop (dedicated energy use) biomass generation for plants completed by December 31, 2001. The credit is 1.5 cents per kilowatthour, in 1992 dollars, and is given to generators for the first 10 years of their operation. In the *CEF* moderate case, the production tax credit for wind and biomass plants was extended to all new plants through December 31, 2004. In the advanced case, this was extended to all nonhydropower renewables, including geothermal, municipal solid waste, and solar.

For the *CEF-JL* cases, the tax credits are incorporated in the same manner as in *CEF*-NEMS. However, in using the modeling structure of *AEO2001*, the minimum number of years estimated to license and complete new power plants using some renewable energy sources exceeds the remaining years of the tax credit, such that the first new power plants could not enter service until 2005, after the expiration of the credit. Therefore, for this case, new renewable plants are allowed to enter service one year earlier than in the reference case, reflecting the incentive that investors would have to complete the units in time to receive the tax credit. In both the *CEF-JL* moderate and advanced cases, a tax credit of 1.0 cent per kilowatthour, in 1992 dollars, is given to coal plants co-firing with biomass in the years 2000 through 2004, the same as in the *CEF* analysis.

Enhanced Research and Development: Renewables and Wind Deployment Facilitation

Many assumptions in the *CEF* analysis were adopted from the *AEO99* high renewables case. In addition, in order to increase the opportunity for wind power, the representation of wind resources and wind generating technologies was modified to lower costs and increase supplies by removing the 1000-megawatt-per-year limit on new wind capacity in any region, reducing the increases in wind capital costs that reflect resource limitations, transmission upgrades, and other market factors, and allowing intermittent wind resources to provide a greater share of overall generation. These modifications are described below.

For the *CEF-JL* cases, assumptions from the *AEO2001* high renewables case are generally used, except where more recent information is more favorable to

[44]Overnight costs are the costs of a new generating unit without including interest charges, contingencies, and overruns. Thus, they represent the costs if the unit could be built "overnight."

[45]Vision 21 is the research and development program for advanced coal and natural gas generating technologies.

renewables or when the *CEF* assumptions are more optimistic. Capital and fixed operating and maintenance costs in both the moderate and advanced cases are generally those used in the *AEO2001* high renewables case. However, the advanced case uses the *CEF* capital cost assumptions for wind power, which were much lower than the costs in the *AEO2001* high renewables case in the early years of the projections but declined much more slowly and by 2020 slightly exceeded the wind capital costs in the *AEO2001* high renewables case. The *CEF-JL* cases use the *CEF* moderate and advanced case capacity factor assumptions, which were taken from DOE's *Renewable Energy Technology Characterizations* and are also used for the *AEO2001* high renewables case. *AEO99* constrained the annual wind capacity growth to 1,000 megawatts in each region. However, this limit is not included in *AEO2001* nor in any of the cases in this analysis.

The *CEF* moderate and advanced cases included a capital cost increase (short-term elasticity) for renewable technologies, depending upon their annual rate of capacity growth in the United States when the annual growth rate exceeded 20 percent. For the *CEF-JL* cases, biomass and wind capital costs increase more slowly than assumed in *CEF*, a 0.5-percent cost increase for every 1 percent increase in annual capacity beyond 50 percent. Solar technology costs increase one percent for every 1 percent capacity expansion beyond 50 percent. These short-term elasticities do not apply to geothermal and hydropower. However, the *CEF-JL* cases limit annual U.S. growth of biomass capacity to 400 percent and wind capacity to 300 percent. The net effect in this analysis should be to make assumptions for renewables as favorable or somewhat more favorable overall than in the *CEF* moderate and advanced cases with respect to the above variables.

In *AEO99*, NEMS included a bound on the intermittent renewable technologies in which the sum of wind and solar generation in each region and each year was limited to a share of total electricity generation, excluding cogeneration. In addition, NEMS apportioned wind resources in each region and applied higher capital costs to each resource portion up to a maximum capital cost increase of 200 percent. These cost increases were meant to reflect the increasing costs of natural resource limitations, upgrades to the existing transmission network, and environmental and other market issues. In the *CEF* analysis, the intermittency bound was completely removed, and the capital cost increases on wind were reduced to a maximum of 60 percent to reflect these costs and the costs of turbine backup and other ancillary costs. Natural resource, transmission, and market costs can reach a maximum of 20 percent, or one-third, of the total maximum capital cost increase in the *CEF* analysis. The *CEF* modifications are incorporated in the current version of NEMS for the *CEF-JL* cases, with the effect of significantly increasing wind supply by lowering the assumed cost of natural resource, transmission, and other market factors.

Although the *CEF* capital cost modifications are incorporated in the *CEF-JL* moderate and advanced cases, the *CEF* assumptions understated important costs necessary in evaluating actual U.S. wind supply. The *CEF* analysis greatly reduced capital cost adjustment factors in NEMS, which were designed to reflect natural resource, transmission, and market factors that add to the cost of wind power, and instead portrayed them primarily as accounting for increasing intermittency costs only. In so doing, the *CEF* analysis provided a useful portrayal of intermittency costs but underestimated more important and greater costs encountered in actual wind power markets.

In wind power markets, natural resource impediments are significant and serve to distinguish low-cost from high-cost sites, including variations in wind quality (peak, off peak), soil (often rock), slope (affecting road and construction cost), weather (moisture, temperature, icing, insects, and storms), and vegetation. Variations affect both the cost of building wind power plants and also their productivity and the costs of accessing and maintaining them. Furthermore, limits on the existing transmission network, separate from interconnection costs, are proving to raise significant barriers to large-scale wind power expansion in all three primary wind areas of the United States (the Midwest, the Northwest and the Southwest), because existing transmission lines lack available capacity for the additional wind power and because increases in uncertain and varying wind power affect the stability of the overall transmission system. Finally, wind power must compete with other interests for the use of land, increasing the costs of wind power as applications expand. Even relatively early in U.S. wind power development, scenic, environmental, and other preferences have been found to be powerful, effective, and costly competitors to wind power expansion. By understating the effects of these factors on the costs of wind power, the *CEF* assumptions overestimated overall U.S. wind supply and underestimated wind power costs.

Renewable Portfolio Standard

CEF included a renewable portfolio standard (requiring a specified percentage of electricity sales to be generated from renewable sources other than hydropower) in the advanced case only. In the *AEO99* version of NEMS, a renewable portfolio standard with a limit on the credit price could not be implemented. Therefore, *CEF*-NEMS modeled a surrogate for a renewable portfolio standard through an extension of the production tax credit until 2008 and an extension of the co-firing credit through 2014. The intention was a 7.5-percent renewable portfolio standard by 2010, maintained through 2015 and subject to a 1.5-cents-per-kilowatthour limit on the credit price. Since NEMS can now explicitly implement this standard, the 7.5-percent renewable portfolio standard is included in the *CEF-JL* advanced case as intended in the *CEF* analysis.

Full National Restructuring

In both the *CEF* moderate and advanced cases, nationwide restructuring of the electricity industry was assumed. This implied that electricity prices would be based on marginal costs, rather than regulated, cost-of-service pricing. The reference case assumes a transition to full competitive pricing in California, New York, New England, the Mid-Atlantic Area Council, and Texas. In addition, electricity prices in the East Central Area Reliability Council, the Mid-America Interconnected Network, the Southwest Power Pool, and the Rocky Mountain Power Area / Arizona (Arizona, New Mexico, Colorado, and eastern Wyoming) regions are assumed to be partially competitive. Some of the States in each of these regions have not taken action to deregulate their pricing of electricity, and in those States prices are assumed to continue to be based on traditional cost-of-service pricing.

The *CEF-JL* cases assume all regions transition to competitive pricing, although the timing of the transition period is delayed slightly based on current assumptions regarding the start of deregulation. Also, there are two regions that have a significant portion of their electricity generated by Federal facilities, which are not a part of deregulation. In those regions, the Southeastern Electric Reliability Council, excluding Florida, and the Northwest Power Pool Area, a portion of the region remains at cost-of-service pricing based on the share of sales met by the Federal facilities. All other regions are assumed to reach 100-percent competitive pricing. Although the *CEF* report discussed changes in discount rates and reserve margins due to restructuring, these changes were not documented. Discussions with *CEF* analysts indicated that no other changes were made to reflect electricity restructuring.

Enhanced Research and Development: Sequestration

The *CEF* authors assumed that technologies using sequestration of CO_2 were allowed to enter the market starting in 2010. The integrated coal-gasification combined cycle and advanced natural gas combined cycle plants were assumed to have higher variable costs due to sequestration, based on a cost of $50 per metric ton carbon equivalent removed. Cost estimates for sequestration methods are very uncertain, due to the lack of experience with the technology. Since the modifications required for sequestration are more like capital investment rather than an increment to the annual operating cost, the *CEF* assumptions are converted to a capital cost adjustment for implementation in the *CEF-JL* advanced case. The additional variable costs are calculated over twenty years and a net present value calculation determines the capital cost adjustments, $550 per kilowatt for integrated coal-gasification combined cycle plants and $270 per kilowatt for advanced combined cycle plants.

These capital cost adjustments are similar in magnitude to those used by EIA in a previous analysis report.[46] However, the EIA analysis includes additional operating costs for the sequestration technology, as well as the capital cost investment. The previous analysis also found that the process of capturing CO_2 greatly reduces the efficiency of the plant, so adjustments are made to heat rates. The *CEF* authors assumed the same heat rate could be achieved by plants using sequestration technology as those without sequestration, which is unlikely.

SO_2 Reductions

As a means of representing tighter standards on particulate matter, the *CEF* advanced case reduced the SO_2 ceiling by 50 percent from the level currently mandated by Phase 2 of CAAA90 (8.95 million tons), declining in steps to 4.48 million tons. The reductions occurred between 2010 and 2020. This particulate matter policy was implemented through SO_2 reductions because particulate matter is likely to be controlled through tighter limits on SO_2 and NO_x since particulates are primarily a byproduct of coal use for electricity generation, although they are also a byproduct of natural gas use. This policy is implemented in the same manner in the *CEF-JL* advanced case.

Impact of *CEF* Policies on Electricity and Renewables Markets

The *CEF-JL* cases have impacts on projected electricity prices in 2020 ranging from a slight reduction in the moderate case to an 8-percent increase in the advanced case (Figure 28 and Table 30). The cost and performance improvements together with the production tax credits for selected renewable technologies result in slightly lower prices in the moderate case. However, the addition of the carbon fee of $50 per metric ton carbon equivalent in the advanced case raises projected electricity prices.

Because of policies in the end-use sectors to reduce energy consumption and the electricity price increases in the advanced case which encourage some additional reductions in the demand for electricity, projected sales

[46]Energy Information Administration, *Impacts of the Kyoto Protocol on U.S. Energy Markets and Economic Activity*, SR / OIAF / 98-03 (Washington, DC, October 1998), web site www.eia.doe.gov / oiaf / kyoto / kyotorpt.html.

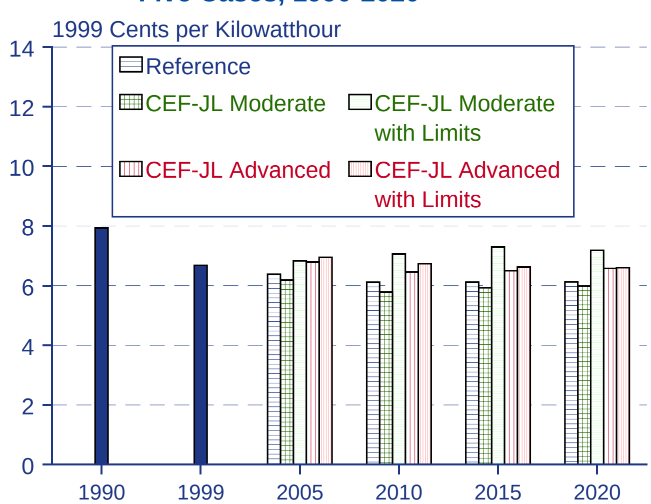
of electricity in 2020 are substantially lower in the *CEF-JL* cases, ranging from 12 percent in the moderate case to 19 percent in the advanced case, compared to the reference case (Figure 29). The *CEF-JL* cases result in annual growth rates of projected electricity sales that are greatly reduced, averaging 1.2 and 0.8 percent in the moderate and advanced cases, respectively, compared with 1.8 percent per year in the reference case. These projected reductions result from *CEF* policies regarding adoption and penetration of more energy-efficient technologies driven by efficiency standards, building codes, financial incentives, research and development, and voluntary agreements and deployment programs, as discussed earlier in this chapter.

The lower levels of projected electricity consumption in the *CEF-JL* cases are expected to reduce the use of fossil fuels to generate electricity (Figure 30). Projected coal-fired generation, which is about the same in the *CEF-JL* moderate case as in the reference case, is 32 percent lower in the *CEF-JL* advanced case in 2020. The projected reduction in the advanced case is partly in response to the carbon fee which makes coal less economic compared with other generating technologies and the policy to reduce particulate emissions. Similarly, projected natural-gas-fired generation declines by 39 percent in the moderate case and by 21 percent in the advanced case in 2020, compared to the reference case. The reduced generation for natural gas is expected to occur because fewer new plants are needed to meet the lower growth in projected electricity demand in the *CEF-JL* cases. However, in the *CEF-JL* advanced case, there are a variety of policies that encourage the use of natural gas and renewable generation instead of coal-fired generation, including the $50 carbon fee and particulate reductions. Nuclear generation is also projected to be lower in 2020 by 2 percent and 6 percent in the *CEF-JL* moderate and advanced cases, respectively, primarily due to the lower generation requirements.

Renewable generating technologies are expected to make little additional contribution in the *CEF-JL* moderate case because natural-gas-fired turbines and combined-cycle plants are still more economic than renewable technologies even with the production tax credits for wind and biomass. However, in the *CEF-JL* advanced case nonhydropower renewable technologies are expected to provide 250 billion kilowatthours of generation, 151 billion kilowatthours more generation in 2020 than in the reference case, due to the extension of the production tax credit for additional renewable technologies, a renewable portfolio standard, and the fee of $50 per metric ton carbon equivalent. As a result, these renewable technologies are expected to increase generation by about 150 percent in 2020 in the *CEF-JL* advanced case, compared to the reference case. Additional generation from wind power accounts for 58 percent of the increase, with biomass, particularly biomass co-fired with coal, providing 21 percent, and geothermal 16 percent of the increase relative to the reference case.

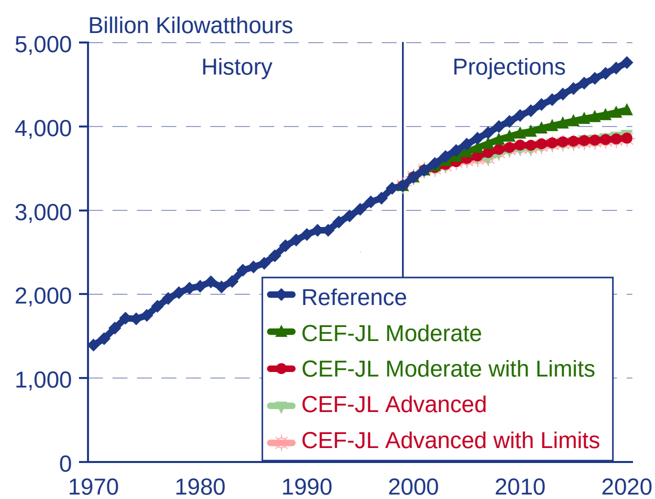
In 2020, projected CO_2 emissions from electricity generation, excluding cogenerators, are reduced by 9 and 32 percent in the moderate and advanced cases, respectively, relative to the reference case.

Figure 28. Average Delivered Electricity Prices in Five Cases, 1990-2020



Source: National Energy Modeling System, runs SCENABS.D080301A, SCENCBS.D080301A, SCENCEM.D081601A, SCENDBS.D092601B, and SCENDEMR.D092701A.

Figure 29. Electricity Sales in Five Cases, 1970-2020



Source: National Energy Modeling System, runs SCENABS.D080301A, SCENCBS.D080301A, SCENCEM.D081601A, SCENDBS.D092601B, and SCENDEMR.D092701A.

Table 30. Electricity Projections in the *CEF-JL* Moderate and Advanced Cases, 2010 and 2020

Projections	1999	Reference	*CEF-JL* Moderate: Without Emissions Limits	*CEF-JL* Moderate: With Emissions Limits	*CEF-JL* Advanced: Without Emissions Limits	*CEF-JL* Advanced: With Emissions Limits
				2010		
Average Delivered Electricity Prices (1999 Cents per Kilowatthour)	6.7	6.1	5.8	7.1	6.5	6.7
Electricity Sales (Billion Kilowatthours)	3,294	4,133	3,920	3,747	3,777	3,745
Generation, Excluding Cogenerators (Billion Kilowatthours)	**3,369**	**4,204**	**3,983**	**3,788**	**3,838**	**3,807**
Coal	1,830	2,238	2,221	1,357	1,737	1,395
Natural Gas	370	826	616	1,138	800	1,090
Nuclear Power	730	720	720	741	735	735
Renewables, Excluding Hydropower	46	95	105	240	253	277
Hydropower	310	301	301	302	302	302
Emissions, Excluding Cogenerators						
SO_2 (Million Tons)	13.5	9.7	9.7	3.0	9.7	3.0
NO_x (Million Tons)	5.4	4.3	4.2	1.7	3.5	1.8
Hg (Tons)	43.4	45.5	45.7	4.3	38.6	4.3
CO_2 (Million Metric Tons Carbon Equivalent)	556	691	658	474	538	475
Allowance Prices						
SO_2 (1999 Dollars per Ton)	0	180	169	316	102	130
NO_x (1999 Dollars per Ton)[a]	0	0	0	0	0	0
Hg (Million 1999 Dollars per Ton)	0	0	0	549	0	481
CO_2 (1999 Dollars per Metric Ton Carbon Equivalent)	0	0	0	64	50	55
Annual Household Electricity Bill (1999 Dollars)	**892**	**936**	**850**	**940**	**882**	**894**
Total Electricity Revenue (Billion 1999 Dollars)	**222**	**252**	**227**	**266**	**246**	**251**
				2020		
Average Delivered Electricity Prices (1999 Cents per Kilowatthour)	6.7	6.1	6.0	7.2	6.6	6.6
Electricity Sales (Billion Kilowatthours)	3,294	4,763	4,197	3,910	3,862	3,855
Generation, Excluding Cogenerators (Billion Kilowatthours)	**3,369**	**4,821**	**4,231**	**3,893**	**3,883**	**3,878**
Coal	1,830	2,302	2,296	1,284	1,567	1,276
Natural Gas	370	1,488	908	1,330	1,181	1,416
Nuclear Power	730	610	595	646	575	617
Renewables, Excluding Hydropower	46	99	113	323	250	260
Hydropower	310	300	300	301	301	301
Emissions, Excluding Cogenerators						
SO_2 (Million Tons)	13.5	9.0	9.0	2.2	4.5	2.2
NO_x (Million Tons)	5.4	4.5	4.3	1.7	3.2	1.6
Hg (Tons)	43.4	45.2	46.2	4.3	29.4	4.3
CO_2 (Million Metric Tons Carbon Equivalent)	556	773	706	474	524	469
Allowance Prices						
SO_2 (1999 Dollars per Ton)	0	200	184	905	707	670
NO_x (1999 Dollars per Ton)[a]	0	0	0	81	0	0
Hg (Million 1999 Dollars per Ton)	0	0	0	468	0	391
CO_2 (1999 Dollars per Metric Ton Carbon Equivalent)	0	0	0	68	50	50
Annual Household Electricity Bill (1999 Dollars)	**892**	**980**	**825**	**884**	**779**	**777**
Total Electricity Revenue (Billion 1999 Dollars)	**222**	**291**	**252**	**282**	**255**	**254**
Cumulative Additions of Emissions Control Equipment, 1999-2020 (Gigawatts)						
SO_2 Scrubbers	—	17.5	9.5	54.9	12.1	52.7
Selective Catalytic Reduction (SCRs)	—	91.1	89.9	112.3	78.6	101.6
Selective Noncatalytic Reduction (SNCRs)	—	46.0	31.9	33.6	33.9	43.4
Hg Fabric Filters	—	0.0	0.0	100.4	0.0	115.5
Hg Spray Coolers	—	0.0	0.0	57.5	0.0	98.3
Cumulative Resource Cost, 2001-2020 (Billion 1999 Dollars)	**—**	**2,031**	**1,751**	**1,913**	**1,682**	**1,811**

[a]Regional NO_x limits are included in the reference case, but the corresponding allowance costs are not included in the table because they are not comparable to a national NO_x limit.

Source: National Energy Modeling System, runs SCENABS.D080301A, SCENCBS.D080301A, SCENCEM.D081601A, SCENDBS.D092601B, and SCENDEMR.D092701A.

Impact of Emissions Limits on Electricity and Renewables Markets in the *CEF-JL* Cases

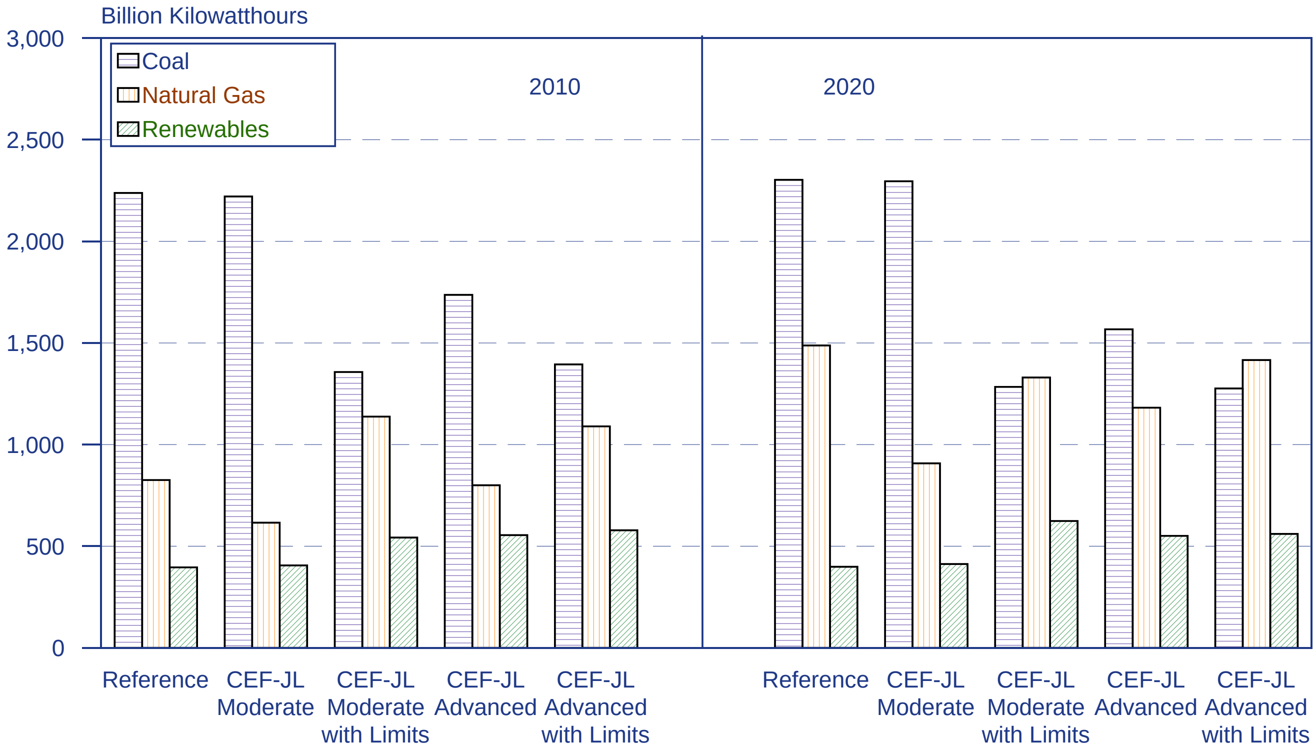
Prices for electricity are generally projected to increase when emissions limits are added to the *CEF-JL* moderate and advanced cases. In the *CEF-JL* moderate case with emissions limits, projected average delivered electricity prices in 2020 reach 7.2 cents per kilowatthour compared to 6.0 cents per kilowatthour in the case without emissions limits, due principally to the costs of meeting the requirements for reductions in CO_2 emissions. In the *CEF-JL* advanced case with limits, the electricity price is projected to be 6.6 cents per kilowatthour, the same as in the *CEF-JL* advanced case without emissions limits.

As in other cases in this report, higher projected electricity prices result in lower levels of electricity sales. In the *CEF-JL* moderate case with emissions limits, projected electricity demand in 2020 is reduced by 7 percent, compared to the case without emissions limits, as a result of consumer responses to higher prices. In the *CEF-JL* advanced case with emissions limits, where projected electricity prices in 2020 are the same as those in the case without limits, projected electricity sales are essentially the same.

The addition of emissions limits to the *CEF-JL* cases is projected to result in less generation from coal and more generation from natural gas. The limits on emissions of CO_2 add to the costs of coal-fired generation making it less attractive compared with natural gas. No new coal plants are expected to be constructed, and more existing coal plants are expected to be retired in the *CEF-JL* cases when emissions limits are imposed. Although natural-gas-fired plants are projected to experience some increases in costs for complying with CO_2 emissions limits, their costs are less than for coal plants because of the lower carbon content of natural gas compared with coal.

In the *CEF-JL* cases with emissions limits, renewable technologies are expected to provide more generation than in the cases without limits, particularly in the moderate case. In the *CEF-JL* moderate case, the CO_2 allowance costs increase the costs of fossil-fired technologies and, as a result, makes the costs of renewable technologies more competitive. Nonhydropower renewable technologies are projected to increase their generation by 210 billion kilowatthours, or 187 percent, in 2020 in the *CEF-JL* moderate case with emissions limits, compared to the case without limits. Only modest increases in renewable generation are projected in the *CEF-JL* advanced case with limits because the advanced case

Figure 30. Projected Electricity Generation from Coal, Natural Gas, and Renewable Fuels (Excluding Cogenerators) in Five Cases, 2010 and 2020



Source: National Energy Modeling System, runs SCENABS.D080301A, SCENCBS.D080301A, SCENCEM.D081601A, SCENDBS.D092601B, and SCENDEMR.D092701A.

without limits already includes a carbon fee. In 2020, nuclear generation is projected to be higher by 9 percent and 7 percent in the *CEF-JL* moderate and advanced cases with emissions limits, compared to the cases without emissions limits as a result of fewer retirements of nuclear plants due to the improved economics of nuclear power relative to fossil-fired generation.

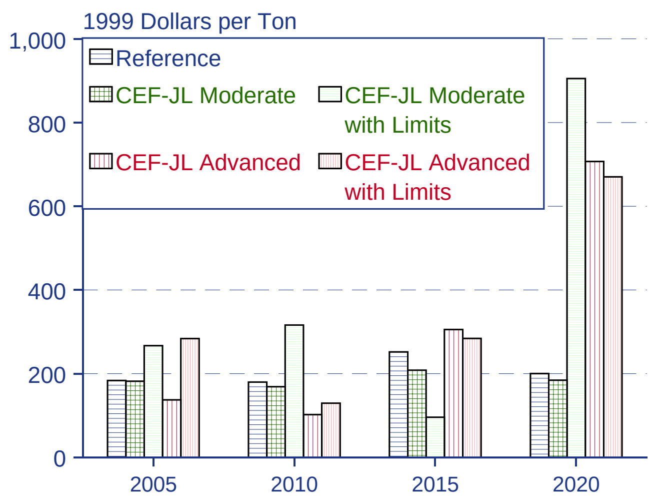
In both the *CEF-JL* moderate and advanced cases, more emission control equipment is projected to be built to reduce emissions of SO_2, NO_x, and Hg when the emissions limits are imposed. About 45 gigawatts of additional SO_2 scrubbers are expected to be constructed in both the *CEF-JL* moderate and advanced cases when the emissions limits are added in order to meet the reduced limits on SO_2 emissions. Similarly, there is also more construction of selective catalytic reduction and selective noncatalytic reduction facilities to meet more stringent reductions in NO_x emissions and investments in fabric filters and spray coolers to reduce emissions of Hg. The lower level of investments for SO_2 controls in the *CEF-JL* advanced case compared with the *CEF-JL* moderate case reflects the lower levels of coal-fired generation that reduce the need to limit emissions. However, there are offsetting additional investments in controls for Hg. These investments are less capital-intensive options compared with those for SO_2 controls.

The costs of SO_2 allowances in 2020 are projected to increase in the moderate case with emissions limits and decrease somewhat in the advanced case with emissions limits. In the *CEF-JL* moderate case with limits, the allowance price is projected to be $905 per ton in 2020, compared to $184 per ton in the case without limits (Figure 31). The projected allowance price in 2020 is $670 and $707 per ton in the *CEF-JL* advanced case, with and without the emissions limits, respectively. The higher projected costs in the *CEF-JL* moderate case reflect the costs of additional emission control equipment constructed to reduce both SO_2 and Hg emissions. In the *CEF-JL* advanced case, the projected allowance price is lower when the emissions limits are imposed, because the limits on CO_2 emissions lower coal use, making it easier to meet the SO_2 limits. In the *CEF-JL* moderate case with emissions limits, the NO_x allowance price is projected to be $81 per ton; however, in the *CEF-JL* advanced case, the projected costs for NO_x permits decline to zero because the actions taken to reduce CO_2 reductions result in NO_x emission levels within the specified limit (Figure 32). Hg allowance costs are projected to be $468 and $391 million per ton in 2020 in the *CEF-JL* moderate and advanced cases with emissions limits, respectively (Figure 33). These costs reflect the cost of adding emission control equipment, such as spray cooling and fabric filters.

Emissions limits on CO_2 result in projected allowance prices in 2020 of $68 per metric ton carbon equivalent and $50 per metric ton carbon equivalent in the *CEF-JL* moderate and advanced cases with emissions limits, respectively (Figure 34). Because the CO_2 allowance price is the same in the *CEF-JL* advanced cases with and without limits, average delivered electricity prices are expected be the same. Projected CO_2 emissions from electricity generators, excluding cogenerators, are reduced by 33 percent and 10 percent in the *CEF-JL* moderate and advanced cases with emissions limits, respectively, compared to the cases without emissions limits.

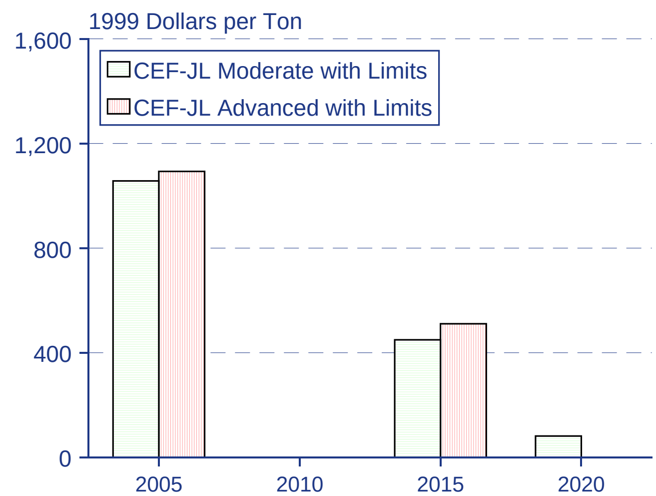
The cumulative incremental resource costs to electricity generators from 2001 to 2020 to comply with the emissions limits are projected to be $162 billion and $129 billion in the *CEF-JL* moderate and advanced cases, respectively (Figure 35), representing increases of about

Figure 31. Sulfur Dioxide Allowance Price in Five Cases, 2005-2020



Source: National Energy Modeling System, runs SCENABS.D080301A, SCENCBS.D080301A, SCENCEM.D081601A, SCENDBS.D092601B, and SCENDEMR.D092701A.

Figure 32. Nitrogen Oxides Allowance Price in Two Cases, 2005-2020

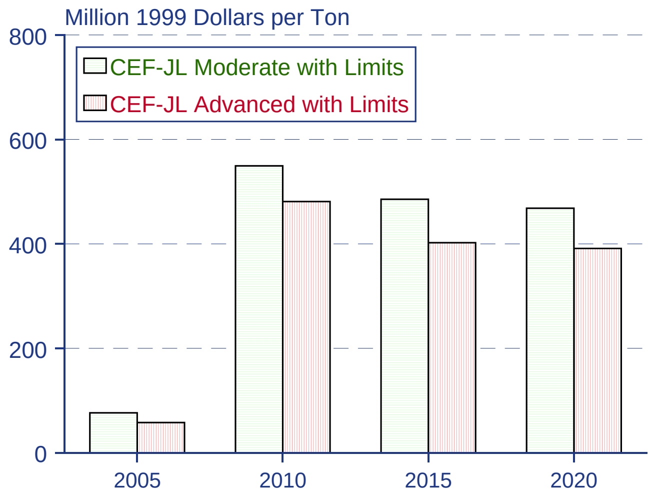


Source: National Energy Modeling System, runs SCENCEM.D081601A and SCENDEMR.D092701A.

9 and 8 percent, respectively. The lower projected cost of compliance in the *CEF-JL* advanced case is due to the availability of more advanced generating technologies compared to the *CEF-JL* moderate case. In addition, because lower SO_2 emissions are assumed in the *CEF-JL* advanced case even without the emissions limits to simulate the impact of particulate controls, the additional emissions limits can be achieved at a lower relative cost.

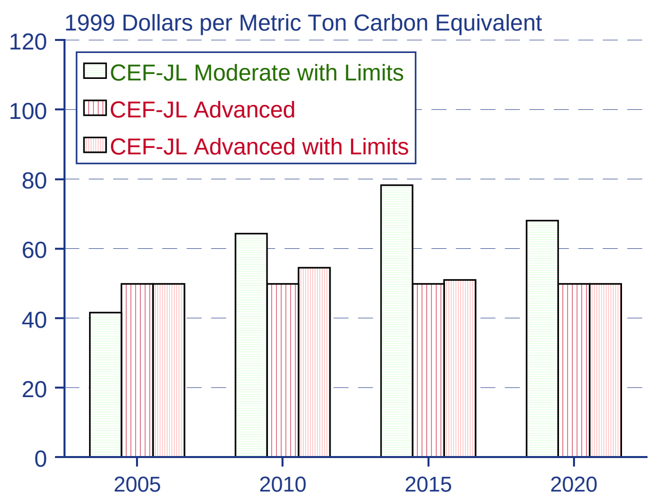
The annualized resource costs, which include financing and capital recovery costs, are projected to increase in the *CEF-JL* moderate case by $18.5 billion in 2007, when the limits are imposed. These incremental costs are projected to decline to $18.1 billion and $14.3 billion in 2010 and 2020, respectively. Similar to the cumulative resource costs, the incremental annualized resource costs due to emissions limits are lower in the *CEF-JL* advanced case than in the *CEF-JL* moderate case, $15.8 billion in 2007, declining to $14.5 billion in 2010 and $11.9 billion in 2020.

Figure 33. Mercury Allowance Price in Two Cases, 2005-2020



Source: National Energy Modeling System, runs SCENCEM.D081601A and SCENDEMR.D092701A.

Figure 34. Carbon Dioxide Allowance Price in Three Cases, 2005-2020



Source: National Energy Modeling System, runs SCENCEM.D081601A, SCENDBS.D092601B, and SCENDEMR.D092701A.

Impact of *CEF* Policies and Emissions Limits on Fossil Fuel Markets

CEF did not include any policies to change the available supply of natural gas or coal but introduced policies to reduce overall energy consumption and change the fuel mix in energy markets. Incorporating the *CEF* policies in the *CEF-JL* cases impacts both natural gas and coal markets as a result of efficiency improvements, demand reductions, and fuel switching.

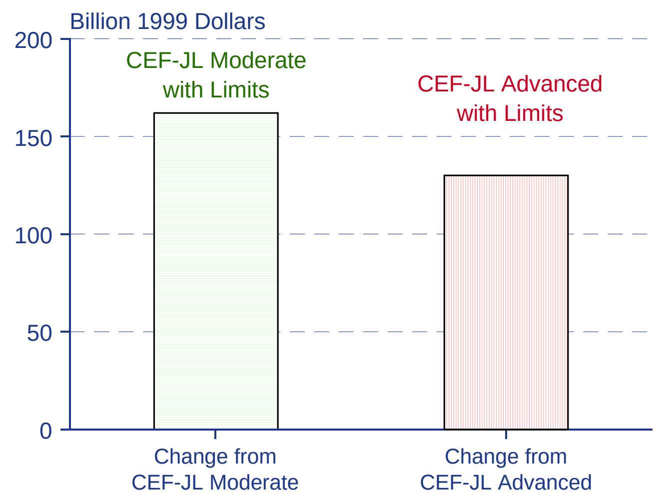
Natural Gas

Impact of CEF Policies on Natural Gas Markets

In 2020, projected natural gas consumption is 30.6 trillion cubic feet in the *CEF-JL* moderate case, compared to 35.0 trillion cubic feet in the reference case (Table 31). Most of the reduction in demand is in the electricity generation sector. In the *CEF-JL* advanced cases, natural gas consumption is projected to be further reduced to 29.9 trillion cubic feet in 2020.

The reduction in natural gas consumption that results from the *CEF* policies is projected to reduce natural gas production and substantially reduce prices. By 2020, total domestic natural gas production is projected to be 25.5 and 24.9 trillion cubic feet in the *CEF-JL* moderate and advanced cases, respectively, compared to 29.3 trillion cubic feet in the reference case (Figure 36). As a

Figure 35. Impacts of Emission Limits on Cumulative Resource Costs for Electricity Generation, 2001-2020



Source: National Energy Modeling System, runs SCENCBS.D080301A, SCENCEM.D081601A, SCENDBS.D092601B, and SCENDEMR.D092701A.

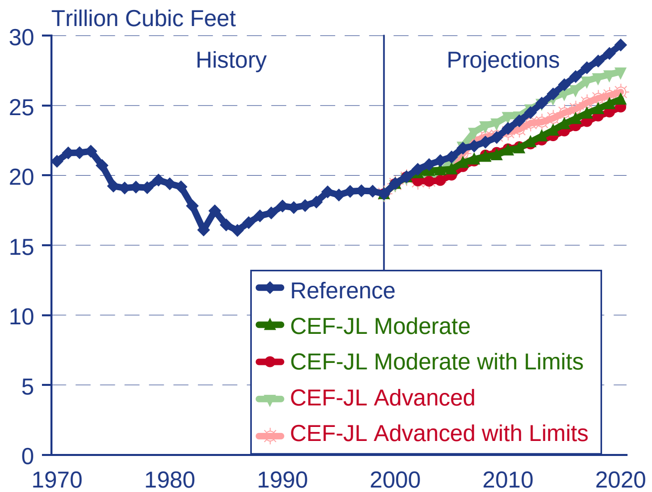
result of the lower demand and production, the wellhead natural gas price is projected to be $2.48 per thousand cubic feet in the *CEF-JL* moderate case and $2.36 per thousand cubic feet in the *CEF-JL* advanced case, compared to $3.10 per thousand cubic feet in the reference case (Figure 37). Lower wellhead prices lead to a 9-percent decrease in the residential price in the *CEF-JL* moderate case, compared to the reference case; however, in the *CEF-JL* advanced case, which includes the $50 carbon fee, the effective residential natural gas price in 2020 is projected to be almost the same as in the reference case. Although the projected wellhead prices in the

Table 31. Natural Gas Market Projections in the *CEF-JL* Moderate and Advanced Cases, 2010 and 2020

Projections	1999	Reference	*CEF-JL* Moderate: Without Emissions Limits	*CEF-JL* Moderate: With Emissions Limits	*CEF-JL* Advanced: Without Emissions Limits	*CEF-JL* Advanced: With Emissions Limits
		2010				
Average Wellhead Price (1999 Dollars per Thousand Cubic Feet)	2.08	2.82	2.45	2.91	2.28	2.76
Delivered Price to Electricity Generators (1999 Dollars per Thousand Cubic Feet)	2.62	3.30	2.88	3.66	2.86	3.48
Effective Delivered Price to Electricity Generators[a] (1999 Dollars per Thousand Cubic Feet)	2.62	3.30	2.88	4.61	3.59	4.28
Consumption by Electricity Generators, Excluding Cogenerators (Trillion Cubic Feet)	3.8	6.8	5.4	8.1	5.8	7.4
Total Consumption (Trillion Cubic Feet)	21.8	28.2	26.4	29.2	26.4	27.9
Domestic Production (Trillion Cubic Feet)	18.7	23.4	21.8	24.2	21.9	23.1
		2020				
Average Wellhead Price (1999 Dollars per Thousand Cubic Feet)	2.08	3.10	2.48	2.82	2.36	2.61
Delivered Price to Electricity Generators (1999 Dollars per Thousand Cubic Feet)	2.62	3.68	2.91	3.57	2.96	3.33
Effective Delivered Price to Electricity Generators[a] (1999 Dollars per Thousand Cubic Feet)	2.62	3.68	2.91	4.57	3.70	4.06
Consumption by Electricity Generators, Excluding Cogenerators (Trillion Cubic Feet)	3.8	11.2	7.4	9.4	7.7	9.2
Total Consumption (Trillion Cubic Feet)	21.8	35.0	30.6	32.9	29.9	31.2
Domestic Production (Trillion Cubic Feet)	18.7	29.3	25.5	27.4	24.9	26.0

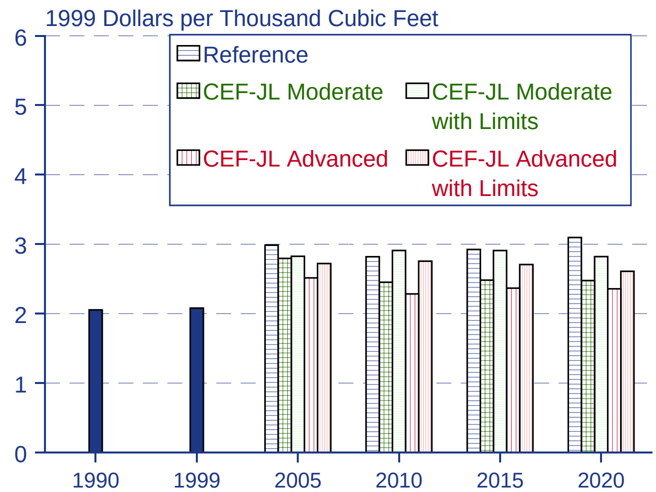
[a]Effective delivered price reflects the cost impact of CO_2 emission allowances in cases that include a CO_2 limit.
Source: National Energy Modeling System, runs SCENABS.D080301A, SCENCBS.D080301A, SCENCEM.D081601A, SCENDBS.D092601B, and SCENDEMR.D092701A.

Figure 36. Natural Gas Production in Five Cases, 1970-2020



Source: National Energy Modeling System, runs SCENABS. D080301A, SCENCBS.D080301A, SCENCEM.D081601A, SCENDBS.D092601B, and SCENDEMR.D092701A.

Figure 37. Natural Gas Wellhead Prices in Five Cases, 1990-2020



Source: National Energy Modeling System, runs SCENABS. D080301A, SCENCBS.D080301A, SCENCEM.D081601A, SCENDBS.D092601B, and SCENDEMR.D092701A.

CEF-JL cases are lower than in the reference case, projected real prices in 2020 are still higher than they were during many of the years in the late 1990s.

Impact of Emissions Limits on Natural Gas Markets in the CEF-JL Cases

Similar to the reference case, imposing the emissions limits results in higher projected natural gas prices and consumption in both the *CEF-JL* moderate and advanced cases, due primarily to higher consumption of natural gas by electricity generators but also due to higher cogeneration in the moderate case. However, even with the higher projected demands in the *CEF-JL* moderate and advanced cases with the emissions limits, compared to the cases without limits, total natural gas consumption and average wellhead prices in 2020 are projected to remain lower than in the reference case.

In the *CEF-JL* moderate case, the projected total consumption of natural gas in 2020 increases from 30.6 trillion cubic feet without the emissions limits to 32.9 trillion cubic feet with the emissions limits, with 1.9 trillion cubic feet of this increase resulting from additional electric generator demand. As a result of the higher demand, the average wellhead price of natural gas in 2020 is projected to increase to $2.82 per thousand cubic feet in the case with emissions limits, compared to $2.48 per thousand cubic feet in the case without emissions limits.

Most of the projected additional demand in the case with the emissions limits is met by increased projected domestic production. Production is projected to reach 27.4 trillion cubic feet in 2020 in the case with the emissions limits, 2.0 trillion cubic feet higher than projected in the case without emissions limits. Similar to the advanced technology case, the increased consumption that results from imposing emissions limits on the *CEF-JL* moderate case does not raise natural gas prices high enough to make additional supplies from Mexico, Alaska, or as liquefied natural gas competitive, and therefore most of the projected growth of supply comes from lower-48 production.

Early in the forecast period, projected natural gas production in the *CEF-JL* moderate case with emissions limits is higher than in the reference case for a few years as electricity generators switch to natural gas to meet the limits. Later in the period, natural gas production and consumption are projected to be lower than in the reference case, and generation requirements are reduced.

The impacts of emissions limits in the *CEF-JL* advanced case are similar to those in the *CEF-JL* moderate case. With projected electric generator natural gas demand increasing from 7.7 to 9.2 trillion cubic feet in 2020 between the case without and with the emissions limits, total consumption is projected to increase from 29.9 to 31.2 trillion cubic feet. Almost all of the additional natural gas required due to the emissions limits is supplied by increased domestic production. By 2020, the projected wellhead price is $2.61 per thousand cubic feet, compared to $2.36 per thousand cubic feet in the *CEF-JL* advanced case without emissions limits. With the emissions limits, the effective residential price of natural gas is projected to reach $7.05 per thousand cubic feet in 2020, compared to $6.77 per thousand cubic feet in the *CEF-JL* advanced case without emissions limits, including the CO_2 allowance cost. This is $0.31, or 5 percent, higher than the residential price projected in the reference case.

Coal

Impact of CEF Policies on Coal Markets

The policies in the *CEF-JL* moderate case generally have a slight impact on coal markets relative to the reference case. Electricity sales are projected to decline as a result of increased adoption of energy-efficient technologies; however, coal is projected to gain market share in the electricity generation market, and projected coal consumption in the generation sector increases at an average annual rate of 1.1 percent over the forecast period, compared to 1.2 percent in the reference case (Table 32).

Several policies in the *CEF-JL* advanced case affect the level of coal-fired electricity generation, including the $50 carbon fee and the reduction in SO_2 emissions to represent tighter particulate matter standards. In addition, various policies for expanding generation by renewable energy sources are introduced or have their expiration dates extended beyond the time period established in the *CEF-JL* moderate case, resulting in an increase of the share of generation from nonhydropower renewable sources.

In the *CEF-JL* advanced case, cumulative retirements of coal plants are projected to total 35 gigawatts by 2020, compared to approximately 7 gigawatts in the reference case. In 2020, coal consumption by electricity generators is projected to decline to 814 million short tons, compared to 1,190 million short tons in the reference case and 1,167 million short tons in the *CEF-JL* moderate case, reducing both coal production and prices (Figures 38 and 39). The more stringent SO_2 requirement leads to a strong shift to sources of low-sulfur coal in the West and results in coal inputs to generators that average 1.5 pounds of SO_2 per million Btu compared to 1.7 pounds in the reference case. Because western coal, with the exception of lignite, also contains lower amounts of Hg and is projected to increase its share of total production, the average Hg content of coal used for electricity generation declines from levels in the *CEF-JL* moderate case.

Impact of Emissions Limits on Coal Markets in the CEF-JL Cases

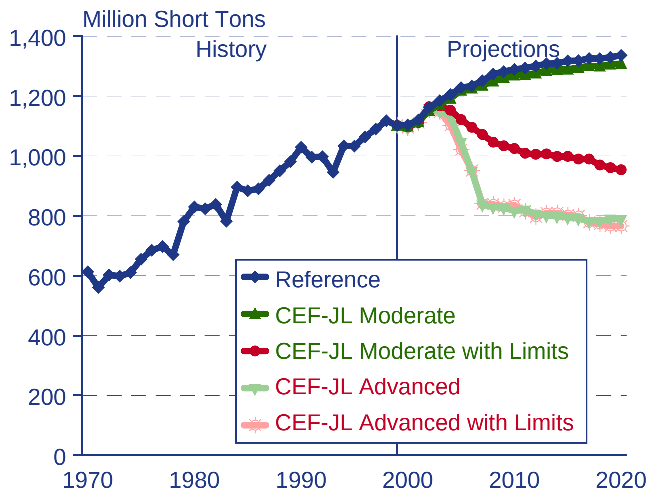
The introduction of emissions limits in the *CEF-JL* moderate and advanced cases is projected to reduce coal consumption by electricity generators in 2020 by 46 percent and 23 percent, respectively, relative to the same cases without the emissions limits. In 2020, the projected CO_2 allowance cost to electricity generators is lower in the *CEF-JL* advanced case with emissions limits than in the *CEF-JL* moderate case with emissions limits, $1.27 per million Btu versus $1.74 per million Btu, because the additional policies to reduce SO_2 and promote renewables are projected to result in a greater reduction in coal consumption and lower CO_2 emissions.

Table 32. Coal Market Projections in the *CEF-JL* Moderate and Advanced Cases, 2010 and 2020

Projections	1999	Reference	*CEF-JL* Moderate: Without Emissions Limits	*CEF-JL* Moderate: With Emissions Limits	*CEF-JL* Advanced: Without Emissions Limits	*CEF-JL* Advanced: With Emissions Limits
		2010				
Consumption by Electricity Generators, Excluding Cogenerators (Million Short Tons)	920	1,139	1,121	658	876	687
Production (Million Short Tons)	1,102	1,289	1,270	817	1,025	836
Minemouth Price (1999 Dollars per Short Ton)	17.13	14.19	13.93	15.08	13.88	14.27
Delivered Price to Electricity Generators (1999 Dollars per Million Btu)	1.21	1.06	1.05	1.00	1.02	1.00
Effective Delivered Price to Electricity Generators[a] (1999 Dollars per Million Btu)	1.21	1.06	1.05	2.64	2.30	2.39
Average SO_2 Content (Pounds per Million Btu)	2.0	1.8	1.8	1.8	1.9	1.8
Average Hg Content (Pounds per Trillion Btu)	7.7	7.2	7.2	6.1	7.6	6.2
CO_2 Allowance Cost (1999 Dollars per Million Btu)	0.00	0.00	0.00	1.64	1.27	1.39
		2020				
Consumption by Electricity Generators, Excluding Cogenerators (Million Short Tons)	920	1,190	1,167	633	814	625
Production (Million Short Tons)	1,102	1,336	1,308	788	954	766
Minemouth Price (1999 Dollars per Short Ton)	17.13	12.93	12.78	13.47	11.51	13.45
Delivered Price to Electricity Generators (1999 Dollars per Million Btu)	1.21	0.98	0.96	0.92	0.93	0.89
Effective Delivered Price to Electricity Generators[a] (1999 Dollars per Million Btu)	1.21	0.98	0.96	2.66	2.21	2.16
Average SO_2 Content (Pounds per Million Btu)	2.0	1.7	1.7	1.7	1.5	1.8
Average Hg Content (Pounds per Trillion Btu)	7.7	7.1	7.1	6.1	7.0	6.2
CO_2 Allowance Cost (1999 Dollars per Million Btu)	0.00	0.00	0.00	1.74	1.28	1.27

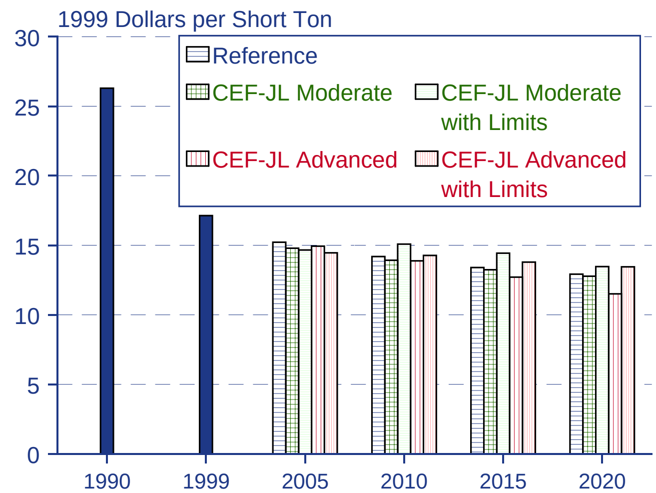
[a]Effective delivered price reflects the cost impact of CO_2 emission allowances in cases that include a CO_2 limit.
Source: National Energy Modeling System, runs SCENABS.D080301A, SCENCBS.D080301A, SCENCEM.D081601A, SCENDBS.D092601B, and SCENDEMR.D092701A.

Figure 38. Coal Production in Five Cases, 1970-2020



Source: National Energy Modeling System, runs SCENABS.D080301A, SCENCBS.D080301A, SCENCEM.D081601A, SCENDBS.D092601B, and SCENDEMR.D092701A.

Figure 39. Coal Minemouth Prices in Five Cases, 1990-2020



Source: National Energy Modeling System, runs SCENABS.D080301A, SCENCBS.D080301A, SCENCEM.D081601A, SCENDBS.D092601B, and SCENDEMR.D092701A.

In the *CEF-JL* moderate and advanced cases with emissions limits, projected coal production in 2020 declines to levels that are 60 percent and 80 percent, respectively, of the coal production in the cases without the limits. Total domestic coal consumption is projected to be lower in the *CEF-JL* advanced case with emissions limits because it includes stronger policies promoting renewable generation sources, which lead to some additional displacement of coal generation. In addition, the application of a $50 carbon fee to the industrial and coking coal sectors is projected to result in reduced consumption of 16 million short tons of higher-sulfur coal in these sectors. Retrofits of scrubbers are projected to be 2 gigawatts less in the *CEF-JL* advanced case with emissions limits, compared to the *CEF-JL* moderate case with emissions limits.

Macroeconomic Impacts

This section analyzes the macroeconomic impacts of emissions limits in the *CEF-JL* cases, using the same methodology described in Chapter 2 for the reference and advanced technology cases, with a marketable emissions permit system and a no-cost allocation of permits.

Macroeconomic Impacts of Emissions Limits on the *CEF-JL* Moderate Case

The *CEF-JL* moderate case incorporates numerous policies to reduce energy consumption and emissions relative to the reference case, which would make the attainment of emissions limits less difficult for the aggregate economy. The introduction of emissions limits in the *CEF-JL* moderate case results in a substantial increase in energy prices and subsequently for aggregate prices for the economy. In the *CEF-JL* moderate case with emissions limits, the wholesale price index for fuel and power (WPI-Fuel and Power) is projected to rise above the case without emissions limits by 12.3 percent in 2007, the first target year for emissions reductions (Table 33). After 2010, the relative increase in this index is projected to decline to 9.9 percent in 2020. Similar to the impacts on the reference and advanced technology cases, the higher electricity and natural gas prices projected for the *CEF-JL* moderate case with emissions limits, compared to the same case without limits, initially affect only the energy portion of the consumer price index (CPI). The higher projected energy prices are expected to be accompanied by general price effects as they are incorporated in the prices of other goods and services. In the *CEF-JL* moderate case with limits, the level of the CPI is projected to be about 0.5 percent above the case without limits by 2007, but the impact on the CPI is expected to be eliminated by 2020.

Imposing emissions limits on the *CEF-JL* moderate case is expected to raise the unemployment rate in 2007 by 0.4 percentage points. Along with the rise in inflation and unemployment, real output of the economy is projected to decline. Real GDP is projected to fall by 0.8 percent relative to the *CEF-JL* moderate case without emissions limits in 2007, and employment in non-agricultural establishments is projected to decline by one million jobs. Similarly, real disposable income is expected to be lower by 0.9 percent.

Table 33. Macroeconomic Impacts of Emissions Limits in the *CEF-JL* Moderate and Advanced Cases, 2007, 2010, and 2020

Projections	2007	2010	2020
Wholesale Price for Fuel and Power (Percent Change From Case Without Limits)			
CEF-JL Moderate Case	12.3	12.1	9.9
CEF-JL Advanced Case	6.9	5.8	3.1
Real Gross Domestic Product (Percent Change From Case Without Limits)			
CEF-JL Moderate Case	-0.8	-0.2	0.0
CEF-JL Advanced Case	-0.4	-0.1	0.0
Consumer Price Index (Percent Change From Case Without Limits)			
CEF-JL Moderate Case	0.5	0.3	0.0
CEF-JL Advanced Case	0.2	0.1	0.0
Unemployment Rate (Change From Case Without Limits)			
CEF-JL Moderate Case	0.4	0.1	0.0
CEF-JL Advanced Case	0.2	0.0	0.0
Disposable Income (Percent Change From Case Without Limits)			
CEF-JL Moderate Case	-0.9	-0.4	-0.2
CEF-JL Advanced Case	-0.4	-0.1	0.0
Nonagricultural Employment (Million Jobs, Change From Case Without Limits)			
CEF-JL Moderate Case	-1.0	-0.4	-0.1
CEF-JL Advanced Case	-0.4	-0.1	0.0

Note: All changes have been rounded to one decimal point.

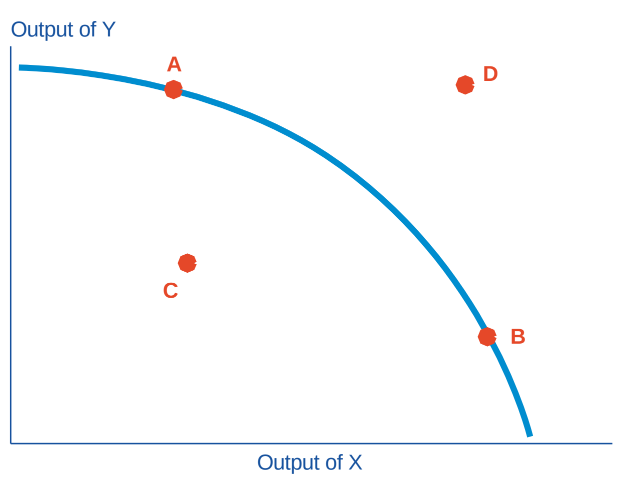
Source: Simulations of the DRI Macroeconomic Model of the U.S. Economy based on National Energy Modeling System, runs SCENCBS.D080301A, SCENCEM.D081601A, SCENDBS.D092601B, and SCENDEMR.D092701A.

Production Possibilities and the U.S. Macroeconomy

A key finding of the *CEF* study was that "there are large-scale market and/or organizational failures, in addition to potentially substantial transaction costs, that prevent consumers and firms from obtaining many energy services at least cost." Moreover, "interpreted in a macroeconomic context, the . . . economy is not on its aggregate production-possibilities frontier."[a]

The production possibilities curve describes the alternative combinations of final goods and services that can be produced in a given time period with all available resources and technologies (see figure below).[b] Points on the curve (points A and B in the figure) represent the maximum level of output that can be produced with a given set of inputs and technology. However, there are multiple ways in which these inputs can be combined to produce any given set of products or services. Movement along the curve introduces another concept, opportunity cost. The opportunity cost reflects a tradeoff in the production of the economy, i.e. to produce more of a product, given a fixed set of inputs, the economy must produce less of something else, or a combination of other goods and services. Points inside the curve (point C) mean that the economy is not fully utilizing its resources and that more goods and services can be produced from the given set of inputs. Points along the curve are said to be "efficient" in the use of a given set of inputs and technologies, while points inside the curve are "inefficient." Production outside of the curve (point D) is not attainable given current resources and technology.

Production Possibilities Curve



As Appendix E-4 of the *CEF* study stated, ". . . many of the criticisms of studies like the CEF are a disagreement with the extent to which the economy is inside its aggregate production frontier, the effectiveness of policies to overcome this situation, or both." The debate also relates to movements along the curve which represent the opportunity cost of changing the mix of goods and services in the economy. The crucial assumption underlying the *CEF* study was that the economy is not currently on its production possibility curve, i.e., the economy is not using its resource base efficiently. Moreover, the study assumed that a least-cost technology modeling approach can yield a measure of the energy cost savings which permits the economy to move outward to the production possibilities curve frontier. However, to do so requires overcoming "large-scale market and/or organizational failures, in addition to potential substantial transaction costs, that prevent consumers and firms from obtaining many energy services at least cost."

Therefore, by assumption, *CEF* presumed that the economy is operating at a position which is not on the stylized "production possibilities curve" and that overcoming market failures in the use of energy can both make the economy more energy efficient (to the position defined as the moderate case) and actually increase GDP at the same time. This assumption was flawed by *CEF* assumptions that energy markets currently are not behaving efficiently and that any of the market barriers that may exist are, in fact, market failures instead, as discussed below. The distinction is important, because as Henry Jacoby points out, "The key difference between market barriers and market failures is that correcting failures may sometimes produce a net benefit, whereas overcoming barriers always involves cost."[c]

However, as discussed in presenting the energy market assessment in this study, many of the presumed "market failures" are actually rational, efficient decisions on the part of consumers given current technology, expected prices for energy and other goods and services, and the value they place on their time to evaluate options. Consumer preferences for certain attributes of energy-consuming equipment, for example, larger cars or houses with increasing use of miscellaneous electric appliances, are consistent with making

(continued on page 81)

[a]Interlaboratory Working Group, *Scenarios for a Clean Energy Future*, ORNL/CON-476 and LBNL-44029 (Oak Ridge National Laboratory, Oak Ridge, TN, and Lawrence Berkeley National Laboratory, Berkeley, CA, November 2000), Appendix E-4, "Estimating Bounds on the Macroeconomic Effects of the CEF Policy Scenarios," web site www.ornl.gov/ORNL/Energy_Eff/CEF-E4.pdf.

[b]B.R. Schiller, *The Macro Economy Today*, Eighth Edition (New York, NY: McGraw-Hill, 2000), pp. 7-10.

[c]H. Jacoby, "The Uses and Misuses of Technology Development as a Component of Climate Change Policy," presentation to the America Council for Capital Formation, Center for Policy Research (October 1998).

Production Possibilities and the U.S. Macroeconomy (Continued)

efficient household decisions. These may represent "barriers" to the adoption of certain energy technologies, but this does not constitute a market failure which prevents the economy from operating on the efficient portion of the production-possibilities curve.[d] Also, many of the programs which are promoted to overcome a market failure overstate the case. Incorrect information can indeed lead consumers to make wrong choices, but benefits of information programs and voluntary initiatives are difficult to quantify.

It is also appropriate to consider a movement along the production-possibility curve to a position that society may deem to be more desirable, for example, one with a lower level of emissions. This is done most often through a change in energy prices vis-a-vis other goods and services, which changes the mix of production and consumption in the economy. However, the carbon trading fee that attains this mix is dependent on the location of the economy relative to the production-possibilities curve. If one presumes that the economy has an alternative reference case with lower emissions, the task of attaining a lower emissions target is lessened. By making this assumption, the *CEF* authors effectively lowered the projected cost of meeting the more stringent emissions targets.

[d]For a good discussion of the distinction between market failures and market barriers, see H. Jacoby, "The Uses and Misuses of Technology Development as a Component of Climate Change Policy," presented to the American Council for Capital Formation, Center for Policy Research (October 1998).

As the economy adjusts to higher energy prices, inflation begins to subside in the forecasts after 2007. At the same time, the economy begins to return to its long-run growth path. By 2020, in the *CEF-JL* moderate case with emissions limits, both the unemployment rate and real GDP are projected to return to the same levels as in the case without emissions limits.

Macroeconomic Impacts of Emissions Limits on the *CEF-JL* Advanced Case

The *CEF-JL* advanced case has lower energy consumption and emissions than the *CEF-JL* moderate case, lowering the cost of attaining emissions limits. Imposing emissions limits on the *CEF-JL* advanced case is projected to raise the WPI-Fuel and Power by 6.9 percent above the level in the same case without emissions limits, compared to a 12.3-percent increase in WPI-Fuel and Power in the *CEF-JL* moderate case. By 2020, the projected increase in the WPI-Fuel and Power by imposing emissions limits in the *CEF-JL* advanced case is only 3.1 percent, compared to a projected 9.9-percent increase caused by imposing the limits on the *CEF-JL* moderate case.

The smaller impact on energy prices in the *CEF-JL* advanced case when emissions limits are imposed, compared to the *CEF-JL* moderate case, results in a smaller impact on prices, employment, and real output in the aggregate economy. The peak impact on the CPI due to the imposition of emissions limits, also in 2007, is projected to be 0.2 percent, compared to 0.5 percent in the *CEF-JL* moderate case. By 2020, in the *CEF-JL* advanced case with emissions limits, both CPI and real GDP return to the same levels as in the case without emissions limits. The imposition of emissions limits is less costly to the aggregate economy as it transitions to a new equilibrium position toward the end of the forecast period. Similar to comparing the impacts of emissions limits between the reference and advanced technology cases, the different levels of energy consumption and emissions in the *CEF-JL* moderate and advanced cases have a significant effect on the magnitude and profile of the impacts on the economy of attaining emissions limits.